

Kentucky Geological Survey,

County Report No. 3

Serial No. 21

The Economic Geology

OF

LEWIS AND ROWAN COUNTIES.

1912

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Lower Part of the Berea, at Alum Rock, Vanceburg, Ky.

Kentucky Geological Survey

CHARLES J. NORWOOD, Director

COUNTY REPORT No. 3

SERIAL No. 21

REPORT ON

The Economic Geology

OF

LEWIS AND ROWAN COUNTIES.

By F. JULIUS FOHS.

1912.

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FRANKFORT, KY., 1924

INDEX.

	Page
Alger fireclay.....	6, 17
Alger formation	4, 6
Ashland Fireclay Company.....	19
Barnett, R., plastic clay on land of.....	22
Barnett quarry section.....	26
Bedford oil and gas sand.....	44
Bradley, Riley Company.....	46
Brassfield limestone.....	3
Buena Vista stone	25, 26, 30, 31, 32, 33, 34
Carver, A. and W., fireclay on lands of.....	18
Clay and shale.....	6, 17, 18, 21
Clay mining.....	18, 21
Clay, refractory at top of Alger formation.....	6
Cement, natural.....	36
Clinton formation.....	3, 35
Coal.....	60
Coal Measures.....	14
Collier, R., fireclay on land of.....	17
Collier's limestone quarry, near Tygert.....	38
Conglomerate Measures.....	14
Corniferous limestone.....	7, 35
Cuyahoga(?) oil sand.....	43
Drilling oil wells, cost of.....	46
Economic values of the Mississippian beds.....	13
Economic values of the Waverly beds.....	10
Fireclay.....	6, 17, 18, 21
Formations, geological, table of.....	2
Freestone.....	25, 26, 29, 30, 31, 32, 33, 34
Freestone, analysis of.....	34
Freestone, physical tests of.....	33
Freestone Company, plant of.....	31
Freestone quarry and mill methods.....	29, 32
Gas wells.....	16
Geological formations.....	2
Glass sand.....	49
Haldeman fireclay.....	17, 18
Harr, I., fireclay on land of.....	17
Homer, P., fireclay on land of.....	17
Hydraulic limestone.....	36
Indian Fields formation.....	3
Iron ore.....	60
Kentucky Bluestone Company, plant of.....	30

	Page
Kentucky Fireclay Company.....	18
Kentucky Ragland Oil Company.....	46
Lawton Limestone Mining Company.....	41
Lawton Sand & Supply Company.....	39, 49
Limestone crushing plant.....	40
Limestone, hydraulic.....	36
Limestone Mining Company.....	39
Limestone near base of Ohio (Devonian) shale.....	8
Limestone quarry methods.....	40
Limestones afforded by the several geological formations.....	35
Limestones, Clinton.....	3, 35
Limestones of Richmond and Maysville formations.....	3, 35
Lithographic stone.....	13, 41
Loyd or Ishma quarry.....	26
Marbles, limestone.....	13, 41
Marl beds.....	14, 23
Mineral springs.....	51
Mississippian limestones.....	13, 35, 38
Monoclines.....	15
Morehead Oil & Gas Company.....	45
Mutual Oil Company.....	46
Oldham horizon.....	4
Ohio shale (Devonian).....	7
Oil and natural gas.....	42
Oil sands.....	43, 44
Oil wells, cost of drilling.....	46
Ores.....	6, 55, 60
Paint shales.....	23
Plum Creek clay.....	4
Portsmouth Granite Brick Company.....	20
Quarries.....	25, 26, 28, 32, 38, 42
Quarries operating in Rowan county, sections at.....	28
Quarry and mill methods for freestone.....	29, 32
Quarry methods for limestone.....	40
Quincy, Lewis county, freestone quarries near.....	25, 26
Ragland oil field.....	16
Ragland oil sand.....	43, 44, 47
Richmond and Maysville formations.....	2, 35
Road materials.....	50
Rowan County Freestone Company, plant of.....	30, 32
Rowan County Freestone Company's shale.....	23
Salt.....	53
Sand and gravel.....	48
Sand used in sawing stone.....	31
Selling prices of stone.....	33
Shales for paints.....	23
Standard Oil Company.....	47

	Page
Stone, selling prices of.....	33
Stratigraphy.....	2
Structure, geological.....	15
Veach, E., fireclay on lands of.....	17
Water supply.....	51, 53
Waverly group.....	8, 9
Waverly beds, economic values of.....	10
West Union limestone.....	6
Zinc ore.....	6, 55, 59
Zinc ore prospects:	
Cadwallar, M.....	59
Campbell, S. B.....	59
Hughes, J. N.....	57
Kennedy, R.....	57
Kinney, T.....	58
Lawhun, S.....	59
Moore, H.....	58
Polly, L.....	58
Regenstein.....	57
Stricklett tunnel.....	58

ILLUSTRATIONS.

Lower part of the Berea, at Alum Rock, Lewis County; from Bulletin 16.....	Frontispiece.
The Buena Vista sandstones, near Farmer, Rowan County; from Bulletin 1.....	Page 24

LETTER OF TRANSMITTAL.

To His Excellency, AUGUSTUS E. WILSON,

Governor of Kentucky.

Sir: I have the honor to transmit herewith a preliminary report on the economic resources of Lewis and Rowan counties, by Mr. F. Julius Fohs. The field work for the report was done in 1909 and the report made ready for the printer by the latter part of April 1910.

Very respectfully,

CHARLES J. NORWOOD,

Director, State Geological Survey.

August 1, 1910.

THE ECONOMIC GEOLOGY OF LEWIS AND ROWAN COUNTIES.

CHAPTER I. INTRODUCTORY,

Lewis and Rowan counties are in northeastern Kentucky. The former has the Ohio river on the north, Mason and Fleming counties on the west and Greenup and Carter counties on the east. Rowan county is immediately south of Lewis, and is bounded on the east by Carter and Elliott, on the south by Morgan, Menefee and Bath, and on the west by Fleming and Bath counties. Lewis and Rowan counties are located between 83° and $83^{\circ} 40'$ longitude west of Greenwich and between 38° and $38^{\circ} 45'$ north latitude. Their areas are roughly 337 square miles in Lewis, and 135 square miles in Rowan county. Vanceburg is the county seat of Lewis county and Morehead of Rowan. The Cincinnati Division of the Chesapeake and Ohio railroad skirts the Ohio river in Lewis county and a small branch road extends from Garrison south into Carter county. The Louisville Division of the same railroad runs southwest across Rowan county, while a small branch road extends south from Morehead to Paragon.

These counties are exceedingly hilly. The hills rise from 400 to 500 feet above the adjacent valleys, or to elevation of 900 to 1100 feet above tide in Lewis and as high as 1200 feet above sea level in Rowan county. The only flats of consequence are in the extreme western part of Lewis county.

Among the more important streams are Salt Lick, Kinniconick, Quicks run, Cabin, and Crooked creeks in Lewis county, with the North fork of Licking river bounding it on the west; and Triplet creek and its forks, principally North, Christy and Dry forks, in Rowan county, with the Licking river and Crany forks on the southern boundary. The Ohio river which bounds Lewis on the north is the only navigable stream.

Stratigraphy.

For the purposes of this report the following stratigraphic divisions have been adopted:

SECTION OF LEWIS AND ROWAN COUNTY ROCKS.

	Feet.
Alluvium.....	0-30
Carboniferous System.	
Pennsylvanian Series:	
Lower Coal Measures.....	93
Conglomerate Formation.....	165
Mississippian Series:	
Mississippian Limestone.....	0-140
Waverly Group (330-435 feet.)	
Cuyahoga Formation.....	200-300
Buena Vista freestone beds near base, (16-29 ft.)	
Sunbury Shale.....	12-17
Bedford-Berea.....	18-128
Devonian System.	
Ohio Shale.....	175-329
Corniferous ? limestone (at least absent in Lewis county).	0-35
Silurian System.	
Niagaran Series:	
West Union limestone (Zinc-bearing horizon).....	25-47
Alger formation.....	100
Clinton formation.....	35
Ordovician System.	
Cincinnatian Series:	
Richmond and Maysville formations, exposed up to.....	200

Richmond and Maysville Formations.—These formations outcrop only in northwestern Lewis county, and on the line with Mason county; near the Ohio river they may be exposed as much as 200 feet. In the hill just south of Concord they are partly exposed for a thickness of about 165 feet. The top of the Richmond is exposed near the mouth of Salt Lick. The most easterly inland exposure is in a branch about one and a half miles east of Concord where the upper part of the Richmond is exposed. One half a mile westward in Sycamore creek lower rocks are exposed. These formations are largely confined to the valleys of Crooked and Cabin creeks, while the North fork of Licking south of Epworth must cut into the Richmond, although there is no exposure. South of Concord, the Saluda sandstone member of the upper Richmond formation may be seen, under which are marly shales with platy limestone partings. These formations carry some rather

pure limestones on Cabin creek, but for the most part consist of shales alternating with thin limestones.

The purer limestones make excellent road metal, may be employed for rough masonry and in part perhaps for lime. The shales being largely marly would carry too much in the way of fluxing materials except for common or paving brick and for sewer pipe.

Clinton Formation.—In this is included all the limestones at the base of the Niagara series in both counties, no attempt being made to differentiate between the Indian Fields formation and Brassfield limestone as separated by Mr. Foerste. In Lewis county only two fair exposures of these limestones and shales were discovered, but neither was complete. One of these on the Vanceburg-Concord road two miles east of Concord, and the other on the Esculapia-Tolesboro road. It is the surface rock at Tolesboro and underlies Burtonville and Epworth at a depth of 10 to 15 feet.

The following general section of the Clinton, as given by W. M. Linney, (Geology of Bath County, Ky. Geological Survey, 1886, p. 175), for Bath county will show the character of this formation. It does not differ much in Lewis or Rowan counties, except that the iron ore is very thin or entirely absent. The limestones are magnesian.

	Feet	Inches
Thin limestones and shales.....	2	
Limestone.....	..	10
Shale.....	1	9
Limestones.....	..	11
Shales and thin limestones.....	4	..
Iron ore (absent in Lewis and Rowan counties).....	2	..
Thin limestone.....	3	..
Limestone.....	1	..
Wave marked layer.....	1	3
Thin limestones.....	3	..
Shales.....	6	..
Heavy (crinoidal) limestone with chert.....	9	..
Total.....	34	9

According to Prof. Foerste (Bulletin 5, pp. 76-77), the upper four members of this section, having a total thickness of five and a half feet, belong to the Oldham horizon while the shales and thin limestones four feet thick represent the Plum Creek section. These two members make up his Indian Fields formation which hence has a thickness of $9\frac{1}{2}$ feet, leaving about 25 feet to represent the Clinton or Brassfield limestone.

The following section was obtained on the Esculapia Tolesboro road:

	Feet	Inches
Alger formation.....	104	..
Clinton formation, 16 ft. 3 in.		
Reddish magnesian limestone.....	2	1
Yellow-green shale.....	3	4
Weathered red and yellow magnesian limestone with thin shale layers.....	2	..
Yellow green shale.....	4	1
Magnesian limestone 3- to 4-inch layers.....	1	..
Yellow-green shale to branch.....	3	9

The magnesian limestones of this formation might do for natural cement, and its shales, will answer for making common brick, sewer pipe and perhaps also for paving brick. This horizon supplies water for Tolesboro and vicinity.

Alger formation.—This is 100 feet thick where exposed in Lewis county. From the sections which follow it will be seen that it consists largely of gray and colored marly shales with occasional thin sandy limestone partings. At the top there is 12 to 14 feet of a rather refractory flint-like clay, but not always present.

The following is a rough section of the hill on Mr. Verner Dryden's place, just south of Pence station, Lewis county and shows the character of the formation:

	Feet	Inches
Red soil.....	18 to 20	..
West Union limestone.....	20 to 25	..
Alger formation:		
Gray, flinty clay, 14 ft.		
Dry, poor clay.....	1	..
Rather hard conchoidal clay, layers up to 8 inches thick	8	..
Thinner, softer, more weathered clay, layers.....	5	..
Sandy limestone parting.....		1 to 2
Gray shale.....	4	..
Parting.....	..	1
Gray shale.....	3	..
Parting.....	..	1
Gray and brown shale with frequent partings.....	6	..
Arenaceous limestone parting two layers.....	..	6
Greenish gray shale with three partings, including basal one.....	3	..
Greenish-gray and purplish brown shale.....	6	6
Green and purple shales with a few thin partings.....	25	..
Shales largely covered.....	24	..
Green shale about 10 feet, exposed.....	7	..
Covered shale including 18 inches red shale at base.....	7	..
Clinton limestones.		
Cincinnati rocks and shales to base of hill.		

The following section was obtained on the west side of the hill which lies between Esculapia and Tolesboro in Lewis county:

	Feet	Inches
Covered.....	13	7
Sunbury		
13 feet, 7 inches	Black shale.....	13 7
Bedford-Berea 44 ft.	Covered, slaty sandstone at top.....	44 4
	Black slate.....	42 6
	Covered.....	23 10
Ohio shale.....	Black and gray slate.....	21 10
174 feet, 10 in.	Covered.....	16 3
	Black slate.....	48 9
	Siliceous and ferruginous slate, gray toward top.....	21 8
	Gray and greenish-gray shale, partly covered.....	55 2
West Union and	Gray shale, (Sample No. 2).....	16 3
Alger formations	Greenish shales, partly covered, about.....	27 2
104 feet.	Deep red and green shales in alternate layers, with thin rock partings.....	5 5
	Reddish magnesian limestone.....	2 1
	Yellow-green shale.....	3 4
Clinton limestone.	Weathered red and yellow magnesian limestone, with thin shale layers.....	2 ..
16 feet, 3 inches	Yellow-green shale.....	4 1
	Magnesian limestone, 3- to 4-inch layers ..	1 ..
	Yellow-green shale to branch.....	3 9

The Alger formation is to be found chiefly in the valleys of the Crooked, Sycamore and Cabin creeks, and along the Ohio river west of Sycamore creek; the top of the formation is exposed occasionally also in Salt Lick, Quicks run and North fork of Licking valleys, and along the Ohio river east of Sycamore creek.

The 12 to 14 feet of refractory clay at the top are suitable for making firebrick and terra cotta ware. A mixture of this clay with the clays below would make good building brick, while the marly shales will do for common and paving brick and sewer pipe, on cutting out the thin limestone layers. These marls would be helpful for their potash content (4 to 5 per cent.) on some soils.

West Union Limestone.—This limestone occurs just beneath the Ohio shale in Lewis county. It has been determined as the equivalent of the West Union limestone of Southern Ohio by Prof. Foerste* and W. C. Morse. The following is a general section of this bed in Lewis county:

Section of West Union Limestone:		Feet
Sandy shale, often absent.....		3
Magnesian limestone, the upper layers often having thin partings of white to black kaolin; the upper 10 to 24 feet carry some brecciated beds which are cemented with zinc blende.....	15-33	
Slightly calcareous sandstone, bluish gray when fresh, and yellowish or reddish when weathered, with sometimes a single 6-inch shale bed 6 feet 6 inches above the base.....		10

This limestone is common to the Ohio river cliffs from Vanceburg almost to Concord, and in the valleys of Salt Lick, Quicks run, Crooked and Cabin creeks. This horizon is characterized by numerous large magnesian and some chalybeate springs. It is also notable because of its carrying zinc ore. It has been used somewhat for natural cement. For road metal it is poor. Further notes will be found on this formation under these several heads. The sandstones are not likely to prove good building stone.

*Fossils from the Kokomo, West Union and Alger Horizons of Indiana, Ohio and Kentucky; The Journal of the Cincinnati Society of Natural History, Vol XXI. No. 1, Sept. 1909, p. 2.

Corniferous Limestone.—In the various oil well records of Rowan county what has been termed by the drillers, the Ragland sand shows a thickness varying from 14 to 35 feet. Hoeing (Bulletin 1, Ky. Geological Survey) classes this as the Corniferous limestone. Prof. Foerste in his sections coming eastward from Spencer, Montgomery county, toward Olympia, Bath county, shows the Corniferous limestone to thin so that a mile south of Preston, Bath county, it is only 8 feet 3 inches thick. Just beneath the Ohio black shale in Lewis county, according to same authority, is the West Union limestone, there being no Corniferous. From this it is necessary to conclude that the Corniferous thins going eastward and either is entirely absent in Rowan county, or it forms only a small part of what has been termed the Ragland sand, part of which must be the West Union limestone. Owing to insufficient data it will be best to tentatively class this oil sand as Corniferous-West Union. The rocks of the two formations are very similar, so much so that it would be difficult except for fossils to tell them apart.

Ohio shale.—This varies in thickness from 175 to 329 feet in Lewis and Rowan counties. In northwestern Lewis it is found even thinner. According to Linney, it is 200 feet thick on the outcrop in Fleming county, and 135 feet in Bath county. According to Hoeing, it thickens rapidly eastward being 450 feet thick in Carter county. The following shows its thickness at a number of points in Lewis and Rowan counties:

	Feet
Alum Rock, not fully exposed, (Lewis).....	242
Slate Point, (Lewis).....	301
Hill between Esculapia and Tolesboro, (Lewis).....	175
Gas well, 12 miles northeast of Morehead, (Rowan).....	329
Alfrey wells, (Rowan).....	220

The uppermost beds are usually of black shale, then come softer light dove and green colored shales, while the lower two-thirds usually consists of black shale, the basal part of which often is siliceous and ferruginous and carries large "nigger heads" of pyrites. The shales are more or

less pyritiferous, which explains the white to yellow crusts of native sulphur and copperas; whence also comes the sulphur and iron for the sulphur and chalybeate springs which these shales afford. On weathering the shales or slate, for some of it is sufficiently compact to be designated "slate," become gray and at times iron-stained.

Regarding a limestone near the base of the shale, Prof. Foerste (Bulletin No. 7, p. 95) says:

"Eight miles east of Owingsville, in the extreme western part of Rowan county, northwest of Moore's ferry, a layer of limestone, thirteen inches thick, containing *Taonurus caudigalli* occurs at or near the base of the Devonian black shale. The rock has a grayish color and apparently belongs to the base of the Black shale series rather than to the Devonian limestone series of more southwestern exposures in Kentucky."

This formation is to be seen on the outcrop in Lewis county as far east on the Ohio river as two miles northeast of Vanceburg. It is found in the hills skirting the valleys of Quicks run, West fork and Salt Lick and chiefly on the east side of Cabin creek and North fork of Licking. In Rowan county, only the top is exposed in the west central portion of the county in the valleys of Triplett and North fork. The best exposures are at Farmers and in the vicinity of Ramey.

The Ohio shale offers little of economic value at present. It can be used for making common vitrified wares, common and paving brick, sewer pipe, and perhaps in Portland cement. At a future time it may be distilled for its hydrocarbon content to make oil, but this cannot be done in competition with petroleum at present. See under oil and gas, for a full discussion of this subject. Its chief importance is due to the sulphur and chalybeate springs which issue from it near its base and give rise to health resorts. (See Water Supply.)

Waverly Group.—This formation covers the greater part of both counties. It varies in thickness from 330 to 435 feet. The top and bottom both are not exposed in any single section. It has been divided into the Cuyahoga,

Sunbury and Bedford-Berea formations by Profs. W. C. Morse and Aug. F. Foerste,* their studies permitting the correlation of the Kentucky beds with those of Ohio. The divisions are as follows:

	Feet	Feet
Cuyahoga formation: up to.....		310
Sandstone shales, worm marked, with occasional 2 to 5 inch sandstone layers at least.....	120	..
Siliceous and ferruginous shales with occasional sandstone layers about.....	50	..
Sandstone beds up to 3 feet thick alternating with thin shale beds.....	85 to 100	..
Buena Vista freestone beds, with thin shales alternating with good freestone ledges.....	16 to 29	..
Red and green shales (Red shales absent in southern Rowan).....	3 to 9	..
Blue to gray clayey shale with occasional sandstone beds sometimes present, and with phosphatic nodules at base.....	6 to 11½	12½-17
Sunbury shale: Black, carbonaceous fissile shale.....	..	18½-128
Bedford-Berea formation.....		
Berea grit: Medium to thick bedded fine to coarse-grained gray ripple marked sandstone with sandy shale, sometimes near base up to.....	22½	..
Bedford member: Sandy and clayey shale with occasional sandlayers, one of which is much contorted, up to.....	95½	..

The Bedford-Berea interval at times is largely made up of sandy and clayey shale, making separation of the Bedford and Berea difficult, especially southward where it thins materially. It must thin only on going southwest for at Freestone it is only 18½ feet thick, whereas in northeastern Rowan it is 119 feet thick if the well record from 12 miles northeast of Morehead is correct, this being thicker than at Alum Rock.

In Lewis county, the Waverly formation covers all the region lying between one mile east of Salt Lick and one-half to one mile west of the eastern county line, also the divides between Quicks run and West fork, between Salt lick and Cabin creek, and the upper part of the divide between Cabin and North fork of Licking. Over half of Rowan county has Waverly rocks at the surface. With the exception of the Licking and the lower parts of Triplett and North fork valleys, the extreme eastern and south-

*The Waverly Formations of East Central Kentucky, Journal of Geology, Vol. XVII, No. 2, 1909, pp. 164-177. Also, Bulletin 16, Ky. Geol. Survey.

eastern parts of the county and capping the highest hills, it is the prevalent formation. The Cuyahoga rocks greatly predominate; the others being noticeable chiefly on hill sides.

The great bulk of the shales are only serviceable for common and paving brick, sewer pipe, etc., as is the black shale of the Sunbury; the latter may some day also be valuable for its oil content. The Buena Vista beds throughout both counties carry excellent building stone. Much of the other stone of the Waverly group may be used for foundations, curbing, flagging, riprap and road metal. The phosphatic nodules at the base are of no special value. The freestone layers often carry good spring waters. The red and green shales, especially the former in the lower Cuyahoga, would do for pigments. Carbonate of iron occurs in some of the shale beds but not in workable quantity.

The following three sections were made by Morse and Foerste and are typical. They show a gradual southwest thinning of the Sunbury and Berea-Bedford formations; the Berea-Bedford changing to sandy shales and showing a thinning of 70 feet in 18 miles. For fuller sections of the Buena Vista member of the lower Cuyahoga reference may be made to the paragraphs under "Freestone" in this report; this member has thinned from 60 feet in southern Ohio to 37 feet at Freestone, Rowan county.

SECTION OF ALUM ROCK, VANCEBURG.

	Feet	Inches	Feet
5. <i>Cuyahoga formation</i>			39
Interval covered except a thick layer of argillaceous sandstone at the top. The sandstone contains <i>Taonurus</i> . Small phosphatic nodules are found in the basal part of the interval.			
4. <i>Sunbury shale</i> , total thickness			15½
Black, fissile carbonaceous shales, which cannot be distinguished, lithologically, from the Ohio shale.			
3. <i>Berea grit</i> , total thickness			22¼
Thick layer of gray sandstone	2	6	
Heavy layer of rather fine-grained gray sandstone, the upper surface excellently ripple-marked	3		
Medium to thick-bedded rather coarse-grained gray sandstones, beautifully ripple-marked (Beds up to 18 inches thick with thin green shale partings)	15		
Arenaceous shales	1		
Layer of fairly coarse-grained gray sandstone		9	
2. <i>Bedford formation</i> , total thickness			95½
Blue arenaceous shales and shaly sandstones. Lower part slightly covered	35		
Arenaceous shales with thin sandstone partings	7		
Layer of thick-bedded gray sandstone	1	8	
Arenaceous shales with two layers of sandstone	6	9	
Heavy layer of gray sandstone, with lower surface contorted	2	4	
Arenaceous shales with two layers of gray sandstone	6	6	
Layer of thick-bedded buff sandstone	1	9	
Medium-bedded gray sandstones with shaly partings	2	10	
Arenaceous pink shales with sandstone partings	2	6	
Covered interval	5		
Layer of thick-bedded, buff sandstone	2		
Practically covered interval with some argillaceous shales	22	6	
1. <i>Ohio shale</i>			242
Black fissile, carbonaceous shales. About ten feet from the top, one or two linguloid shells occur. Near the central part the shales become softer and lighter in color and resemble a similar zone in the Ohio at Columbus, (Ohio). The interval (242), is mostly exposed and extends to the level of the Chesapeake and Ohio Railroad. At "Slate Point," however, the top and bottom contacts are shown and the total thickness is 301¼ feet.			

PETERSVILLE SECTION.

	Feet	Inches	Feet
4. <i>Cuyahoga formation</i>			55½
Medium to heavy-bedded, gray, argillaceous sandstones with shaly partings.....	14		
Covered interval.....	41	6	
3. <i>Sunbury shale</i> , total thickness.....			12½
Black, fissile carbonaceous shales.....			
2. <i>Bedford-Berea</i> , total thickness.....			46½
Covered, except some arenaceous and calcareous shales, which are probably ripple-marked.....	14		
Bluish to buff arenaceous shales with an occasional parting, ripple-marked.....	17	6	
Blue, argillaceous to arenaceous shales with an occasional calcareous or arenaceous parting.....	7		
Thin layer of sandstone.....		5	
Blue, argillaceous shales with a little black, carbonaceous shale at the base.....	4	3	
Covered interval.....	2	6	
Soft, argillaceous shales mixed with some black shales.....		9	
1. <i>Ohio shale</i>			85
Black, carbonaceous shales slightly covered.....	85		
Covered, to the water level of Kinniconick Creek at the church.....	10		

SECTION AT FREESTONE (ROCKVILLE) STATION

	Feet	Inches	Feet
Soil to the level of the peneplain.....	15		
4. <i>Cuyahoga formation</i>			90
Soft, blue, argillaceous shales with an occasional ferruginous parting. The lower two feet covered, but probably shales.....	35		
Soft, blue, argillaceous shales alternating with thin to medium-bedded argillaceous sandstones, the shales predominating.....	18		
Top of the Buena Vista member and also the top of the stone quarried. Even-bedded argillaceous sandstones, "freestones," with thin partings of blue argillaceous shales. The sandstones contain <i>Taonurus</i> . The layers are mostly medium-bedded, that is, of proper thickness for commercial use. Their size together with the shaly partings render them easily quarried. They are quite extensively worked and make a beautiful and excellent stone.....	25	6	
Soft, blue, argillaceous shales with three or four shaly sandstone partings which contain <i>Taonurus</i>	4	6	
Soft, blue argillaceous shales.....	7		
3. <i>Sunbury shale</i> , total thickness.....			16¼
Black, fissile carbonaceous shale.....			
2. <i>Bedford-Berea</i> , total thickness.....			18½
Soft, blue, argillaceous and finely arenaceous shales, and fine-grained shaly sandstone. The lower two feet have one or two thin layers of black, fissile shale.....			
1. <i>Ohio shale</i>			20¾
Black, fissile, carbonaceous shales.....	2		
Covered to the level of the Chesapeake & Ohio Railway. Exposures in a nearby gully and the main stream show, however, that all of this interval is Ohio shale.....	18	9	

Mississippian Limestones.—There was not time at my disposal for a sufficient study of these rocks to determine their equivalency, so I have adopted the noncommittal group name, Mississippian limestone, as sufficient for the purposes of this report. The variability of thickness of these rocks is very striking in this section of the State and was earlier pointed out by Prof A. R. Crandall.* The following table shows this variability—from 0 to 140 feet.

	Feet
Hill back of Springville, Carter county (Crandall).....	0
Head of Indian run, Lewis county (Crandall).....	Several
Head of Shultz creek, Carter-Lewis county (Crandall).....	A few.
Kentucky Furnace lands, Carter county (Crandall).....	10-20
Boone Furnace lands, Greenup.....	80-100
One mile from Deep cut, Lewis county, includes about 10-12 feet shales at base (Fohs).....	42
Carter Caves, Carter county (Crandall).....	140
Colliers quarry, at Berry Switch, near Tygert, Carter county, including shales at top (Fohs).....	93½
Morehead hill, Rowan county (Fohs).....	15
Near head of Christie branch of Triplett creek, Rowan county (Owen).....	30
Near head of Dry creek and Wagner fork of Caney creek, Rowan county, including concealed space of 10 feet at top (Fohs).....	42
Hill west of Yale, Bath county, typical of southwestern Rowan and adjacent parts of Bath and Menefee counties (Fohs).....	98
Natural Bridge, Wolfe county (Fohs) about.....	150
Stanton, Powell county, exposed.....	109½

This formation is confined to a narrow outcrop on the west side of the hills on the eastern edge of Lewis county and likewise to a narrow outcrop on the hills of eastern and southeastern Rowan county, and occurs as a capping beneath a thin bed of the conglomerate on many outlying hills west of this line in Rowan county. It caps the hills on either side of the Licking from Yale southeast, and follows up Caney and Wagner fork.

Much of this limestone is sufficiently pure for use in connection with shales for the making of Portland cement. It makes fine road metal and flux. There is some lithographic stone but it is flawed too much to be of value except for small stones. Then there are brown marbles

*Geology of Greenup, Carter and Boyd counties and a part of Lawrence County. Kentucky Geological Survey, Vol. C., pp. 6-7, 1884.

that are suitable for interior decorations, and oolites for building stones. The marl beds, improved by burning, but capable of use without would be suitable for use in improving the sandy soils of these and adjacent hills. A few good springs mark the line of outcrop. For detailed sections see under Limestone, where the uses are also fully discussed.

Conglomerate and Lower Coal Measures.—The following section from near the head of Dry creek and Wagner fork of Craney creek shows the maximum thickness of these measures in Rowan County:

	Feet.
Coal Measures.	
Debris and sandstone	10
Slate with gravelly iron ore	22
Coal, spring water at base, 10 inches to	1
Sandstones and ferruginous shales	70
Conglomerate.	
Coarse, sometimes cross-bedded sandstones and shales about	150
Coal, locally 18 inches to 3 feet, then slate, a bone coal, and cannel slate	7 to 10
Refractory clay, mottled with plant impressions	5 to 8
Mississippian limestones and shales, including covered interval at top ..	42

The conglomerate and lower coal measures cap the hills of southeastern Rowan between Christy branch of Triplett and Miners branch of North fork of Licking, and the head waters of Tygert Creek (Carter county) and Triplett creeks. Going north they become thinner so that on the dividing ridge between Lewis and Greenup counties the conglomerate and a lesser thickness of the coal measures show. These measures form but a narrow strip in eastern Lewis. Many of the outlying hills of eastern Lewis and Rowan counties are capped with the conglomerate sandstone. At Morehead the hill has at least 65 feet of such capping.

The coal measures offer nothing of special economic interest, while the base conglomerate measures offer a thin coal which may be thick enough in places for local use, a bed of good refractory clay, and some sandstone suitable

for glass-sand and concrete. Locally there is a bed of red ochre.

Alluvium. Residual Clays, etc.—This is chiefly confined to a narrow strip of Ohio river bottom land and to some of the creeks. It may reach a depth of 20 to 30 feet. The hills often show a like thickness of residual clays, sands and boulders.

It offers some sand which will answer for building and molding purposes, and gravels which are serviceable for road metal.

Structure.

Only a general outline of the structure of these counties can now be given, both for lack of a map upon which to base accurate work and lack of a dependable barometer the greater part of the time.

Taken alone the structure suggests two nearly parallel monoclines, the axes of which strike and pitch northeast. These probably form, however, a part of the great geanticline, commonly known as the Cincinnati anticline, the main axis of which also strikes and pitches northeast (at least from Jessamine county northward) and which axis passes through eastern Pendleton county about 40 miles west from Rowan and Lewis counties. The monoclinal folds of the latter counties, then, are roughly parallel to the main axis of the Cincinnati anticline and constitute minor folds on its eastern flank. The limbs of these monoclinal folds dip southeast. The effect of these folds is to bring almost upon the same level, successively the formations from the Richmond-Maysville in Northwestern Lewis, to lower coal measures in eastern Lewis and Rowan counties. The change in formations northeast through these counties is far less marked.

These general conclusions are based upon the following estimates of the dip of strata. The varying thicknesses of the strata as well as lack of data as to the probable original slope of the sea bottom make it impossible to say when or how the uplift or downthrow took place and just what its full extent was, even though we had fuller and more accurate data as to location and elevation of points connected with the several formations. However, the

amount of dip is sufficient to overbalance these other factors, thereby proving a general structure such as has been previously outlined.

The axis of the first of these monoclines, the presence of which Linney pointed out (see *Geology of Bath and Fleming counties*, p. 83), as a marked disturbance in Fleming county and as probably passing northeast in Lewis county, has a general trend of N. 35-40° E. It passes probably immediately east of Burtonville, and Tolesboro, about two miles east of Poplar Flat and crosses the Ohio river about two miles southeast of Concord.

It is marked by a line of outlying hills capped with higher formations. No data is available as to the dip of the western limb and but meager data of that of its eastern limb. The latter dips 23 feet per mile southeast between Tolesboro and Esculapia.

The second monocline has a general trend of N. 25° E. and the main axis runs from the vicinity of Ragland, Bath county, northeast west of Morehead and east of Vanceburg. The axis pitches northeast about 3½ feet per mile. The western limb dips southeast about 5 feet per mile; while the eastern limb dips southeast at the rate of 50 feet per mile in northern Lewis to about 65 feet per mile in southern Rowan. These estimates are based on the top of the Ohio shale as a dip plane for there is less likelihood of unconformability than in any of the other formations. The dips based on the other formations vary somewhat from these but it is believed that these approach an average. Prof. Crandall* has figured the slope of the top of the Waverly along a line from Morehead to northern Carter county at 3½ feet per mile, which corresponds to the figure given above based on the top of the Ohio shale.

The axis of this monocline may have some relation to the Ragland oil field, and when the counties have been topographically mapped it may be possible to definitely locate this axis, which may guide the more intelligent locating of a few wells to settle the question of oil and gas northeast of the Ragland field. It is interesting to note that the gas wells northwest of Triplett P. O., and the wells on Cherry Camp approach the line of this axis.

*Vol. C., Ky. Geological Survey, *Geology of Carter, Greenup and Boyd Counties*, 1884.

CHAPTER II. ECONOMIC GEOLOGY.

Clay and Shale.—Fireclay is found at two horizons, the top of the Alger formation and at the base of the conglomerate.

The most notable exposure seen of the Alger fireclay is on the Verner Dryden place one-half mile south of Pence Station, three miles west of Concord, Lewis county. This bed is 14 feet thick in the outcrop. For details of the section see the Alger formation. The analysis given below shows this to be a fireclay of fair quality, burning red-buff. Similar clay usually occurs at this horizon elsewhere in Lewis county notably east of Poplar Flats at the base of Herron hill; and is to be looked for where the magnesia springs issue just beneath the West Union limestone.

The clay at the base of the conglomerate is a high grade fireclay and was formerly worked in Lewis county and is now worked at Haldeman, Rowan county.

From about 1880 to 1902 fireclay was mined to a considerable extent in Lewis county by the Charles Taylor Co., on the hills up Briery creek. The clay beds were on the Ed. Veach and Peter Homer lands. On the former the clay varied from 1 to 11 feet, averaging 3½ feet thick, while on the Homer the average was 4 feet. The clay comes in 3 layers, the uppermost 6 to 15 inches of white clay, then 6 to 12 inches of dark clay, and white clay below, one to several feet thick. The clay bed is capped by the Conglomerate sandstone containing abundant plant impressions, while beneath the clay the Mississippian limestone is covered. This clay is also found on the Robert Collier land adjoining, and is said to have been opened recently on the Ike Harr land at the head of Shultz creek.

The clay was hauled to Quincy, about 3 miles distant at a cost of 75 cents per ton. It was barged to Cincinnati in 300 to 500 ton bargeloads, and brought \$2.25 per ton delivered.

On the line between Lewis and Carter counties, one mile west from Deep Cut, a deposit of fireclay at the base

of the Conglomerate was worked in 1901 on the Alfred Jordan and Bill Carver lands. The following section was obtained here:

	Feet	Inches
Sandstone.....	2	
Gray shale.....		8
Fireclay, an iron seam in 8 inches of base.....	2	

The clay is said to be 11 feet or more thick on the Trace (Lewis county) side of the ridge.

The Kentucky Fireclay Company (L. P. Haldeman, Pres., 402 Masonic Bldg., Portsmouth, and Henry K. Leighow, Gen. Mgr.) have their mine and plant at Haldeman, eight miles east of Morehead on the Louisville branch of the C. & O. R. R., and near the line between Carter and Rowan counties, but in the latter. It was erected in 1903, though the mine was opened previously. No. 1 and No. 2 firebrick, also buff building brick, are made.

The section at the mine is as follows:

Black slate.....	1 ft. 6 in to 2 ft.
Bone coal.....	
No. 2 clay.....	
Flint clay.....	1 ft. 3 in. to 1 ft. 8 in.
No. 2 clay.....	2 ft. 8 in. to 3 ft. 8 in.
Soft sandstone.....	6 in. to 3 ft.
Red clay.....	

The flint clay is used in conjunction with the No. 2 clay in making the firebrick, the No. 1 firebrick carrying a greater proportion of the flint clay. The No. 2 clay is used alone in making the building brick. The brick made are of excellent quality.

The clay is mined on the room and pillar system. The main entry is 8 to 10 feet wide and 30 feet long. The rooms are 100 to 200 feet long, 18 to 20 feet wide and 6 to 8 feet high 7 feet on the average, and are timbered with 6 to 10 inch stulls. The holes are drilled with a 1½ inch augur, 4 feet deep, and are filled with 12 to 14 inches of powder. The holes are usually placed two horizontal and two upward inclined 3 to 4 feet apart, in two rows, one above the other just below the flint band, and the shooting

is done at noon and at night. Oil is burned for light. The men employed and wages paid are as follows: 12 clay diggers, contract at 20 to 25 cents per ton (each room produces 10 tons or about 12 cars per day); 3 drivers 12½ cents per hour; 2 trappers 7½ cents per hour; and 12½ cents per hour; the shift is of 10 hours.

The clay is dumped into four bins, capacity 40 tons each, from whence it is trammed to the plant below as required. The clay for the firebrick is ground in two Stephenson wet pans, capacity 20,000 per 10 hours, hand moulded and sanded and wheeled to the drying floor, where they are dried on sand. The clay for the building brick is ground in the McClaren dry pans, thence it is mixed with water in an American Clay Machine pug mill, and thence to the cutting machine which cuts nine bricks at a time. There is one large drying floor and three upper smaller ones for drying various shapes. The capacity is about 50,000 bricks per day. There are seven round kilns, 18 feet in diameter, 9 feet to the crown; and three square, two of which are 15 x 50 feet, and one 16 x 32 feet. The walls are 27 inches thick. The kilns vary in capacity from 45,000 to 56,000 bricks each. About 100 men and boys are employed at the plant, the wages paid running from 75 cents to \$2.25 per 10 hours.

The Ashland Firebrick Co., have a mine and plant just over in Carter county, and a description will be given here for comparison with that at Haldeman. The mine is at Shay, and the Hayward plant at Enterprise, though some of the clay is shipped to the four other plants of the company two of which are at Ashland and two at Ironton. W. B. Seaton is president of the company, and Mr. McConnel is the Hayward plant manager. The latter plant was opened in 1899 and the mine two years earlier.

The stratigraphic succession at the mine is sandstone; slate 10 feet; fireclay 6 feet; sandstone and red shale; Mississippian limestone; Waverly sandstone. The fireclay has an 18 inch band of flint clay at the top, and occasionally 2 feet at the bottom. The rest of the bed is more plastic. The following is an analysis of the flint clay, taken from Bulletin 6, Ky. Geol. Survey, pp. 190-192.

"No. 2661 N. S. A hard gray flint clay. No effervescence with hydrochloric acid. No phosphoric acid." Analyzed by S. D. Averitt, 1905.

Moisture.....	0.88
Ignition (combined water and volatile matter)	13.24
Silica.....	45.56
Alumina.....	35.75
Ferrie oxide.....	0.87
Lime.....	0.28
Magnesia.....	0.40
Potash.....	0.59
Soda.....	0.39
Titanium dioxide.....	1.80
Sulphur trioxide.....	0.40
	100.16

The clay is mined by the room and pillar system. Two mules and four cars are used, the drivers being paid \$1.40 per day; seven or eight miners are employed. The clay is taken out on contract at 20 to 25 cents per ton. The total cost per ton is about 30 cents. There is a small tram road about a mile long connecting Shay and the plant.

The clay is permitted to weather at least 8 or 10 days prior to using. Some of the clay is calcined in a calcining kiln, that is to say, the volatile matter is expelled and it becomes dry and friable. Four shovels of the calcined product is used to each barrow of 109 inches of brick in order to prevent shrinkage. The brick are hand moulded and sanded. The sand is obtained from the Clark land across the railroad. It is a residual sand. It costs 65 cents per ton; 400 lbs. being used per day per 8000 bricks, the capacity of the plant. There are two wet pans employed and one square and four round kilns. The round kilns are 26 feet in diameter and have a 36 inch wall, and have a height of 8 feet to the crown. The square kiln is 16 x 30 feet. The storage shed has a capacity of about 1½ millions of brick.

Paving brick are made by the Portsmouth Granite Brick Company at Firebrick, 18 miles northeast of Vanceburg. The plant is reached by a short switch from the

C. & O. Railroad. Formerly firebrick were made at this plant, the white and gray striped fireclay being brought from the tops of the hills just over in Greenup, but of late Olive Hill clay has been used instead. Building brick are also made here, but the efforts are now chiefly confined to paving brick.

The products used in making the paving brick are obtained just to one side of the plant. A gray block shale 20 to 30 feet thick is used in conjunction with the residual clay and sand debris 10 to 15 feet thick which cap it, 40 parts of the shale being used to 60 of the residual product. The building brick are made from shale, and shale, iron etc. half and half from on top of the hill about one mile back from the plant. A blue-black shale cuts into the block shale, and is over 6 feet thick; this is said to be unsuited for use in the paving brick.

The clay is quarried by undermining, by drilling horizontal holes four feet deep and shot with dynamite. The sand and clay debris are loosened by drilling vertical holes 16 to 18 feet deep and the shooting is done with powder. Four men are used in quarrying the shale and a like number for the sand and clay.

The clay and shale are trammed to the dump and then shoveled to the grinding pans.

The plant consists of one 7½ foot wet pan and two 9-foot dry pans with ⅛ inch perforated bottoms. The wet pan is used in the making of the firebrick only. The ground product is elevated to a stationary gravity screen (4 x 20 feet) with ⅛ inch perforations, inclined 45°; the oversize is tailed back to the pans. The undersize passes to a 12-foot pug mill where it is mixed with water to a proper consistency. It is then ready for the American Clay Workers press with automatic cut off, consisting of three bars which each cut eight bricks at a time, a capacity of 20,000 per ten hours. The brick pass to a double die Eagle re-press, after which they are ready for the drying floor which is 60 by 85 feet and then for the kilns. Of these there are 15, nine of which are square and six round. The square kilns are 18 by 32 feet in the clear and 8 to 12 feet high with side walls 27 inches and end walls 22 inches

thick. These kilns have a capacity of 50,000 building-, 40,000 fire-, or 33,000 paving-brick. The round kilns are 28 feet in diameter, a height of 9 feet to the spring of the crown, with walls 27 inches thick, and have a capacity of 43,000 to 44,000 paving-brick.

The power is supplied by a 240 horse-power engine and two boilers of 300 horse-power.

Sixty men are employed when the plant is in full blast. When the hill quarries were going, as many as 175 were employed. The quarry foreman gets \$1.50 per 10 hours, the quarry men \$1.20. The engineer gets \$1.90 and the workman at the plant \$1.20.

A mottled red and green plastic clay 3 feet or more thick and under 6 to 7 feet of cover, was exposed in a branch on Robert Barnett's land back of Ruggle's store, one-half mile up Briery creek from Quincy, Lewis county. This same clay was found in the wells on both Robert Barnett's and his son's land for about one-half mile further up the valley on the south side of the creek.

The shales connected with the Rowan County Freestone Company's quarry are described below:

No. 2625.—Shale from the stripping of the Rowan County Freestone Company's quarry at Farmers. The shale lies immediately above the stone. Thickness, forty-two inches. Average sample of hard, dark gray shale, somewhat soapy to the touch. Geological position, Waverly. Analysis of air-dried sample by A. M. Peter, 1905.

No. 2626.—Mixed shale, lying above 2625, with an interval of ten feet between the two. Thickness, four to ten feet. An average sample of mostly greenish rather soft shale, but with some brown shale. Geological position, Waverly. Analysis of air-dried sample by A. M. Peter.

	No. 2625	No. 2626
Moisture.....	1.07	1.02
Ignition.....	6.47	6.25
Silica.....	59.64	59.44
Alumina.....	21.49	18.93
Ferric oxide.....	4.22	6.59
Lime.....	0.28	0.36
Magnesia.....	1.19	1.30
Potash.....	3.51	3.45
Soda and trace of lithia.....	0.47	0.42
Titanic oxide.....	1.25	1.25
Sulphur trioxide.....	trace	trace
	99.59	99.01

Each sample should make good brick, either paving or builder's, if properly prepared and burned.

Gray micaceous, siliceous and ferruginous shales occur on the east side of the ridge between Stricklett and Esculapia on the Long branch road.

About 120 feet below the top of the hill, about the base of the Cuyahoga, is a 6-foot bed of gray siliceous clay.

Red and chocolate colored shales suitable for use in cheap paints were noted as follows:

A bed four to six feet thick on Vanceburg hill two miles south of Vanceburg. This is in the Cuyahoga below the Buena Vista freestone. This same bed was noted on the Town branch hill to the east. This bed was also noted on the ridge northwest of Fruit. A green shale invariably occurs below the red bed.

One and a half miles south of Carrs is a 5-foot bed of chocolate colored shales in the Alger formation.

About four or four and a half miles east or north from Tolesboro, the following section was obtained:

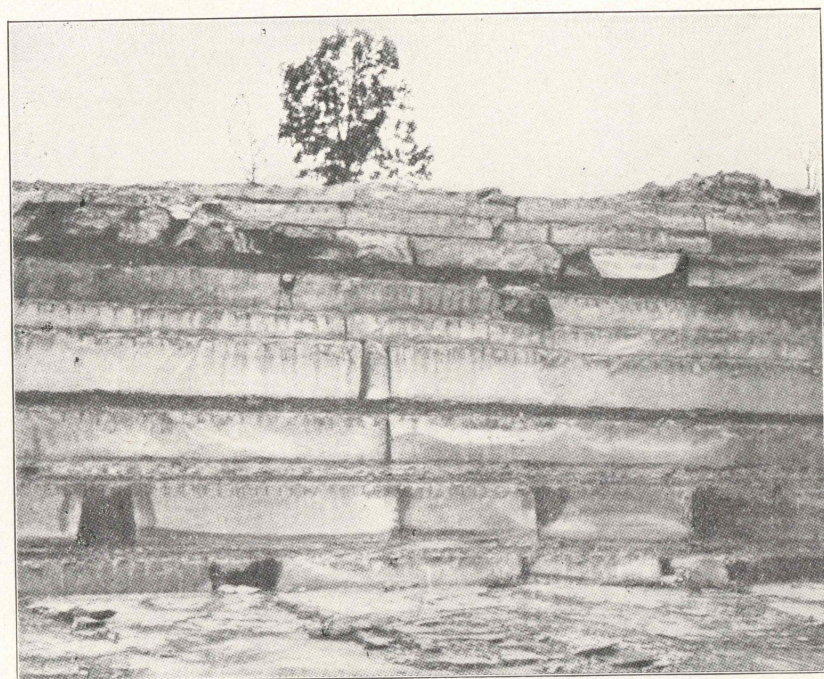
	Feet	Inches
Siliceous limestone of Clinton at top.		
Siliceous shale..... 1 to	1	4
Reddish shale.....	1	10
Greenish shale.....	1	
Slaty sandstone toward base.		

The following analysis is quoted here to show the character of the marls interbedded with the Mississippian limestones. It is taken from Bulletin No. 6, "Some Kentucky Clays," pp. 188-189.

No. 2461. Marl.—"From mines of Carter County Limestone Mfg. Co. Found in their quarry, in a bed about three feet thick. Supposed to be useful as a fertilizer."

"A compact marl, of chocolate and dirty green color. Adheres to the tongue. Soft enough to be scratched by the nail."

"As this contains a considerable percentage of carbonate of lime and magnesia, as well as a fair proportion of phosphoric acid and 3 per cent. of potash, which, how-



Buena Vista Sandstones, near Farmer, Rowan County.

ever, would not be immediately available as a fertilizer, this marl may be found beneficial on poor sandy soil in its immediate vicinity, where the cost of transportation would not preclude its use."

Analysis of the air-dried sample of the marl is as follows:

	Percent.
Water and loss.....	2.37
Silica.....	58.44
Alumina.....	13.37
Ferric oxide.....	5.00
Lime carbonate.....	13.88
Magnesia carbonate.....	3.42
Potash.....	3.02
Soda.....	0.28
Phosphoric acid.....	0.20
	99.98

Freestone.—Lewis and Rowan counties yield a fine quality of freestone commonly known to the trade as Kentucky bluestone. It occurs in what are called the Buena Vista beds (it having first been quarried at Buena Vista, Ohio), from 9 to 200 feet above the base of the Cuyahoga formation. These beds have a thickness of 16 to 29 feet, of which from 9 to 13 feet is good stone, some of the remainder being valuable for ballast, rough masonry, etc. The beds are separated by thin layers of shale and hence are easily quarried. The ledges vary from 6 to 30 inches thick. The thickness of each bed is fairly constant in each quarry, but the beds differ in thickness slightly in the different quarries. The stone is blue-gray in color which on weathering becomes a gray-buff. It is sawed for building stone, flagging and curbing, while the rougher rock is used for foundations, rough masonry, for road metal, concrete, etc. The stone underlies the hills of a section of country 7 to 14 miles wide and about 32 miles long. The general bend of the strip is lightly northeast and runs from Quincy in northeastern Lewis county, almost to Cogswell in southwestern Rowan county. This means a minimum of over two billion yards of good stone.

Of this however, not more than one-fourth would be accessible; that is have sufficiently light covering to admit of profitable quarrying. Then, too, there is a large amount not now accessible to transportation.

The total production of sandstone in Kentucky is really small compared with what it should be.

In the vicinity of Quincy, Lewis county, the stone has been quarried since 1885, in considerable quantities, up to 1906, after which the production declined.

The following is a list of the quarries which have been opened there: Robert Anderson, Squire B. F. Branhan, Woodworth, T. J. Loper, Mrs. Hughes, Samuel Ormiller, and J. L. Scott. According to the proprietor there were eight good ledges at the last named quarry, which were 6, 10, 12, 12, 14, 15, 18, and 20 inches thick.

The Robt. Barnett quarry is just back of J. T. Ruggles' store, $\frac{1}{2}$ mile up Briery creek from Quincy, on the south side of the creek.

One mile south of Loyd's station, between Quincy and Garrison, is the Loyd or Ishma quarry, operated in 1907. These quarries are all so caved that it was impossible to measure up a single section. At many of them the stone has been removed as far back as under present conditions it would be profitable to quarry it, owing to depth of cover.

Below are given sections typical of the quarry beds:

Robert Barnett Quarry Section as reported by Mr. Barnett:

	Inches.
Black shale above.....	8
Good freestone.....	18
Freestone.....	5
Freestone.....	5
Good freestone.....	12
Good freestone.....	14
Good freestone.....	10
Good freestone.....	12
Freestone with iron seams, "Iron ledge".....	10
Good freestone.....	16
Shale.....	1½

	Inches.
Freestone with iron seams.....	12
Freestone.....	8
Good freestone.....	14
Freestone.....	8
Slate.....	6
Good freestone.....	18
Slate.....	6
Good freestone.....	18

The stone at this quarry is gray fine-grained, some beds having yellow-brown iron streaks up to $\frac{1}{2}$ inch wide parallel to the bedding planes. The upper surfaces of the rock are rough and usually shaly. The stone on weathering becomes a dirty gray-brown in color.

Section on hill in Lewis county, between Glenn Springs P. O., and Meyer's store, about a mile from the latter, beginning at an elevation of about 160 feet above the post-office.

	Inches.
Sandstone.....	5
Shale.....	6
Sandstone.....	12
Shale.....	1½
Sandstone.....	18
Shale.....	2
Sandstone, irregular, and seamed in upper part, 40 to...	20
Sandstone.....	20
Shale.....	1
Sandstone.....	20
Slaty sandstone.....	6
Sandstone.....	24
Sandstone.....	6
Sandstone.....	10
Slaty sandstone.....	6
Sandstone.....	17
Slaty sandstone.....	1
Sandstone.....	4
Slaty sandstone 2 to.....	1
Sandstone.....	16
Covered.....	2
Sandstone.....	12
Shale.....	2
Sandstone 18 to.....	16
Shale 6 to.....	8
Sandstone.....	6
Slaty sandstone and shale.....	2 to 4
Sandstone, uneven surface.....	8 to 5
Slaty sandstone and shale.....	6
Shaly sandstone.....	3 to 4
Sandstone.....	12

	Inches.
Slaty sandstone and shale.....	2
Sandstone.....	22
Shale.....	6
Sandstone, uneven top.....	18 to 16
Shale.....	4 to 6
Sandstone.....	14
Ferruginous sandstone.....	2½
Sandstone.....	6
Covered 10 feet, below which is Sunbury shale.	

In the 28 feet 11 inches exposed there are an unusually large number of what appear freestone beds of good quality, the distance from the railroad alone precluding their present use.

SECTIONS AT OPERATING QUARRIES, ROWAN COUNTY.

Bluestone	In.	Freestone	In.	Farmer	In.
Freestone, poor...	6	.....	4	Freestone, poor...	6
Shale.....	1	.....	1	.....	5
Freestone.....	10	.....	11	.....	13
Shale.....	1	.....	1	.....	1
Freestone.....	12	.....	12	.....	12
Shale.....	2	.....	2	.....	2
Hard iron rock...	8	..... 8 to	8.5	.....	.....
Iron seamed sandstone.....	.....	.....	.....	.....	.....
Shale.....	10	.....	11	.....	.....
Iron seamed sandstone.....	15	Dark and discolored for masonry	16	.....	18
Shale.....	1	.....	1	.....	.....
Freestone.....	8	For foundations...	10	.....	.....
Shale.....	14	.....	2	.....	14
Free-stone. { <i>Taonurus</i> extends 1½" into stone	19	Fine 18½ to.....	18	.....	18
Shale and thin rock.....	3	} Iron carbonate and shale...	7	{	15
Shale.....	7.5				
Free-stone.. { <i>Taonurus</i> extends ¼ in. into stone...	17	Fine 20 to.....	19	.....	.....
Shale.....	5	Shale and iron carbonate.....	6	.....	.....

SECTIONS AT OPERATING QUARRIES, ROWAN COUNTY—Continued.

Bluestone	In.	Freestone	In.	Farmers	In.
Freestone.....	8	For street crossings.....	8	.....	.....
Shale.....	4	.....	5	.....	.....
Freestone, best grade.....	21	Suitable for bridge work, nice stone but slightly laminated, marked, and has blind seams..	30	Best grade.....	30
Shale and thin rock.....	10	Rock and shale...	8	.....	.....
Freestone, poor...	5	.....	2	.....	.....
Shale.....	2.5	Shale.....	4	.....	6
Freestone, best grade.....	16	.....	23	.....	22
Shale.....	2	.....	2	.....	10
Freestone, best grade.....	26	Sells for 30 inch. Defects 6 inches deep at top and is darker for 4 inches at base.....	32	Best grade.....	27
Freestone, hard...	8	Floor of quarry...	.....	Shale.....	6
Floor of quarry...	.....	.....	.....	Floor of quarry covered.....	14
				Greenish blue shale ..	8
				Sunbury black fissile shale.....	20
				Bedford-Berea arenaceous shales.	.....

The overburden, consisting of residual clay and shale, shows maximum thickness of 10 to 25 feet.

The plug and feather system is employed in quarrying the stone. One-inch holes are drilled 6 inches apart and 6 inches deep, after which the plugs are evenly driven until the stone is broken.

At one of the quarries the stripping is done by means of a hoist, hard-pan plow, and scrapers both being operated automatically much like a steam shovel, only by means of cables with a man to guide plow and scraper.

The slaty shale above the stone at the Robt. Barnett quarry is lifted by drilling horizontal holes, with an auger, six feet deep. The holes are sprung with 1 inch of dynamite after which one-half keg of powder (4X) is used. This takes off as much as 18 feet of cover 30 to 60 feet back from the face. Eighteen feet is the maximum depth of cover profitable to remove.

The Rowan County Freestone Company's plant erected in 1903 is housed in a building 120 feet long, 50 feet wide, and 20 feet to eaves, with 8 feet to top of roof. It has six New Albany Mfg. Co., saw gangs, three of which are 11 feet 8 inches (mostly for flagstones), two 13 feet 8 inches, and one 17 feet 8 inches long. The saws are of soft steel 4 inches wide by 2-16 to 3-16 inches thick. They are operated at the rate of 100 to 105 revolutions per minute. Sharp sand is used in connection with the saws and is imported from Ottawa, Illinois. Above each saw gang is a shaker screen with 1 inch perforations which scatters the water and sand to saws. A four-inch centrifugal pump is used to supply water and sand by 1½ inch pipe. But a ⅜ inch stream of water is required for this purpose. The sand overflow is worn out, hence it goes on waste dump.

Power is supplied by a 150 horse-power Atlas boiler, which consumes 2.78 tons of coal per day, and a four-valve 13 x 18 inch Atlas engine. Water is supplied by a Dean Steam pump, 3 inch suction, 2½ inch discharge. The water is pumped from Triplett creek nearly.

The yard is supplied with an electric crane (New Albany Mfg. Co. make) 200 feet long, 50 feet wide, 22 feet high for handling the stone. A 250 volt generator making 975 r. p. m. supplies power for lights and crane.

A 12 x 14-inch Ingersoll-Sergeant compressor supplies air for the rock drills.

A crusher and screens for making ballast, etc., were added in 1910; also two of the latest pattern, Owens saw gangs.

Twenty men are employed in the quarry and seven in the mill.

The Kentucky Bluestone Co., has been in operation since 1886. The plant contains six Clogsdon saw gangs, 6 x 11 feet (made by Rainey, Rockland, Vt.) A 1,000-ft. 4-inch pipe line supplies water by means of a No. 5 Cameron pump for the 100 barrel tank at quarry. Power is supplied by an 85 horsepower Erie tubular boiler and 80 horsepower engine. Four 20 horse-power, double drum, double cylinder hoists are used on the yard and in the quarry. Five steam Ingersoll-Rand rock drills are in use. This

company has erected nine cottages for the benefit of its workmen, and one office and residence building for its superintendent. Six men are employed at the plant and sixteen in the quarry.

In 1910, this company installed, in addition, a crushing plant of 250 tons capacity, consisting of the following: One 60-foot elevator, one No. 4 Austin gyratory crusher, one 16 foot trommel screen separating stone into 5 sizes from 2½ inch down to dust, a 50 horsepower horizontal tubular boiler, and a 35 horsepower steam engine, all of which are housed in a new building. Steam hoists and derricks are provided for the preliminary handling of the stone.

The Freestone Company's quarry was opened in 1881. The plant has five saw gangs cutting 200 cubic feet of stone per day. The sizes of the gangs are as follows:

Two.....	5 by 9 ft.
One.....	5 ft. 9 in. by 10 ft.
One.....	8 by 10 ft.
One.....	4 ft. 6 in. by 12 ft. 6 in.

Elk River, W. Va. sand is used. Fourteen men are employed at quarry and four at the plant. The yard is supplied with three hoists, an incline for tail rope haulage, with 1½ inch cable. A 40-horsepower engine and a boiler of like size are required for this. A 25-horsepower boiler supplies steam for two Ingersoll-Rand rock drills.

The cost of sand for sawing varies with quality and locality from which obtained, as follows:

	Cu. yd.	Freight	Total
Ohio river sand, Ashland, Ky.....	\$0.65	\$0.65	\$1.30
Elk River sand, Charleston, West Virginia.....	.75	.85	1.60
Ottawa Silica Co., Ottawa, Illinois.....	.65	2.20	2.85

The cost of labor per 10 hours is as follows:

Foreman, lawyers and helpers.....	\$2.00 to	\$2.75
Drillers, Engineers and Hoistman.....	..	1.75
Drillers' helpers.....	1.40 to	1.50
Firemen.....	..	1.25

The Rowan County Freestone Co. has a bonus system in vogue, paying 2 cents per cubic foot for all above 20 feet sawed by the six gangs. The bonus is prorated among the mill men and foreman according to the wages paid them. This has increased the average amount of stone sawed per hour from 20 feet to over 30 feet.

The costs are placed by one company as follows:

Sawing.....	8 cents per cubic foot.
Quarrying.....	4 cents per cubic foot.
Office and sales	8 cents per cubic foot.
Total	22 cents per cubic foot.

The cost of stripping surface debris at one of the quarries using hoist, scraper, and shovel was 14 cents per cubic yard.

Another company places the total cost of producing the stone f. o. b. cars at 30 cents per cubic foot., while a third company places the cost of quarrying the stone, good and bad, aside from surface stripping at \$1.00 per cubic yard.

The cost of a plant for sawing and quarrying stone runs from \$20,000 to \$28,000.

The stone from the quarries at Quincy cost as follows, delivered to the railroad yard, when last quarried:

Royalty.....	.10
Quarrying.....	.75 to .85
Haulage.....	.25, .40, and .55

The cost of labor was then \$1.00, \$1.10, \$1.25 and \$1.40 per 10 hours, but now is \$1.50 per day, which would increase the cost to \$1.40 or \$1.50 per cubic yard.

The waste uncrushed product goes for ballast, first grade bluestone for building, second grade for bridges, culverts, etc.

The demand was better in 1909 than in 1908 in general keeping with recovery of trade. Concrete interferes with the demand for rough stone but not with that for building purposes. In 1910 there was practically no change.

The selling price of the stone varies somewhat within the following limits, depending on grade and demand for sizes:

Rough stone per cubic yard:

30-inch stone.....	\$1.00
Low grade, all sizes.....	\$1.00-1.60
11-, 12-, and 16-inch, good grade	1.75
8-inch, good grade.....	2.00
10-inch, extra quality.....	2.25
Bridge stone.....	\$1.50-4.00
Average value 1910 f. o. b. quarry.....	.99
Sawed stone per cubic foot:	
Sawed once, two sides smooth.....	.30
Sawed twice, four sides smooth.....	.50 to .55
Slightly inferior stone 1 to 2 cents less per cubic foot.	
Average value, 1910, f. o. b. quarry.....	.35
Sawed flagging per square foot:	
2 to 4 inch.....	.06 to .14
Average value, 1910, f. o. b. quarry.....	.06 1/4
Riprap stone: 99 cents per cubic yard.	
Concrete rock: 46 1/4 cents per ton.	

The stone from the Quincy quarries prior to 1908 brought \$1.50, and in 1908 and 1909 it brought \$1.75 per cubic yard, none being sold in 1910.

Comparison of the physical characteristics of the stone with that of other states is very favorable, proving it a stone well above the average:

	Ky. Bluestone.	Other Sandstone	Limestones
Crushing strength per sq.in	11,750 to 16,327	3,000 to 24,625	4,326 to 31,957
Specific gravity.....	2.50 to 2.67	2.04 to 2.727	2.48 to 2.841
Weight pounds per cu. ft..	141.75	113.1 to 162.5	147 to 177
Percent absorption.....	3.99 to 10.02	4.81 to 22.62	.53 to 12-18

Care should be taken by the quarryman to select only the best stone (which is done by the sawing plants in Rowan) and to season the stone well so as to free it from quarry water.

The Southern Bithulitic Co., of Nashville, had the iron seamed rock of the Rowan County Freestone Company tested for macadam purposes at the laboratory of Warren Bros. Co., Boston. (Test No. 23,190.) Results were as follows:

	Per cent.
Abrasion in air.....	11.6
Abrasion in water	11.2
Sp. Gr.....	2.71
Absorption.....	0.3

ANALYSES OF KENTUCKY FREESTONE.

	Farmers	Farmers	Rowan County, Freestone Co. Quarry. 27 inch ledge.	Ky. Blue-stone Co. Quarry. Pittsburg testing Laboratories.
	No. 1221 Dr. R. Peter	No. 2429 Dr. R. Peter		
Silica.....	90.240a	93.128a	85.96	84.60
Alumina.....	3.965	3.339	6.82	7.26
Oxide of iron.....			2.34	1.86
Manganese.....			Trace	....
Lime.....	0.829	0.324	0.65	0.55
Magnesia.....	0.932	0.256	0.72	0.60
Sulphur trioxide.....	0.219	0.256	Trace	....
Soda.....	0.089	....	1.45	0.39
Potash.....	0.336	....	0.74	1.94
Phosphoric acid.....	0.117	....	....	....
Water at 100.....	2.900	2.514	0.19	2.40
Ignition loss.....	0.62	1.140	1.38	

a—Includes insoluble silicates.

No. 1221, (Vol. 4, Old Series, Ky. Geol. Survey, 1861, p. 252) Dr. Robert Peter gave the above analysis from the mouth of Triplett Creek, edge of Rowan county. He describes it as a fine-grained gray sandstone. Adheres to the tongue. Powder nearly white. Specific gravity 2.539. Dried at 212°, its powder lost 0.40 per cent of moisture.

No. 2429 (Chemical Analyses, Part 2, Ky. Geol. Survey, 1885, p. 238), is an analysis also by Dr. Robert Peter of a sample from the quarry near Farmers station. He describes it as a fine-grained sandstone of a handsome light gray color on the recently exposed surface, showing a few minute spangles of mica. Adheres to the tongue. Stained light ochreous and brownish on the weathered surfaces. Showing no fossil remains, but *Spirophyton caudi-galli* (Hall) on one of its surfaces. This rock was used in the construction of the new Court House at Lexington. Specific gravity 2.50.

Some of the buildings in which the stone has been used are:

Y. M. C. A. Building, Ashland, Ky.; Central Christian Church, Lexington, Ky.; Residence of Mr. Lowry, and Odd Fellows Temple, Mt. Sterling, Ky.; C. & O. Depot, Richmond, Va.; C. & O. Depot, Charleston, W. Va., C. &

O. Depot, Ashland, Ky.; Biggs, Watts & Co., Dry Goods Store, and Johnson Memorial Church, Huntington, W. Va.

Limestone.—These counties afford limestone at a number of geological horizons, the general character of and the uses for which adapted may be stated as follows:

Maysville-Richmond Limestones.—These are somewhat siliceous, calcareous limestones; make good road metal and some beds are adapted for burning into lime; the best is on Cabin creek.

Clinton, Corniferous and West Union limestones.—These are all of similar character; only the Corniferous is not found in outcrop. These limestones are markedly magnesian and ferruginous, and to some extent siliceous, grading at times into calcareous sandstones. These limestones hardly contain sufficient silica and alumina to make first-rate natural cements. As they decompose badly they do not make good road metal either. The high percentage of magnesia makes them valueless for lime.

Mississippian limestones.—These beds vary greatly in character and the formation in thickness, also. The different beds and their uses may be summed up as follows: Oolitic or slightly siliceous oolitic limestone and the compact crystalline rather pure calcareous limestones are suitable for building stone, lime, portland cement, good flux, road metal and agricultural lime (that is pulverized for correcting acidity in soils); compact gray siliceous limestones for road metal and flux; very fine, compact flawless limestone for lithograph stone; flinty limestone for road metal; brown marble and siliceous crinoidal beds for interior decoration; compact argillaceous limestone for natural cement; and thin magnesian beds of no particular values.

Profitable quarries could no doubt be opened where the beds are sufficiently near transportation. For example, in Lewis county in the Maysville-Richmond limestones west of Concord, and in the Mississippian limestones in the vicinity of Deep cut; and in Rowan county, in the Mississippian limestone, in the hills north and south of Halde-

man, between Morehead and Paragon, and in the southwestern corner of the county near Yale.

Further details and some sections follow which may be helpful to those who may have an interest in the limestone.

Natural cement rock.—Limestone which carries usually from 15 to 40 per cent. of silicates, clay, etc., so that when treated with coal slack to a temperature above that at which carbonic dioxide is given off and below that of clinking in kilns not unlike those used in lime-making it will produce a product which will not slack but will set and harden under water after being pulverized, is known as natural cement. Since the character of such a product varies within wide limits, the properties of the resulting product will also vary widely. Not only in this but also in lighter weight, quicker set, and lower ultimate strength do they differ from the artificially prepared Portland cement. For these reasons the production and use of natural cement is on the decrease as compared with Portland cement, especially in regions where Portland cement plants are available. The nearest plant in this instance being at Ironton, Ohio, forty miles distant, which makes doubtful the success of a natural cement plant in Lewis or Rowan counties.

The Mississippian rocks sometimes offer a better rock for this purpose; see Dilz creek section.

An attempt to manufacture natural cement in Lewis county, which proved unsuccessful, is described below:

On the George S. Love place 5 miles west of Vanceburg and about 1 mile south of Quicks Run bridge is a bed of hydraulic limestone. The upper twelve feet while not regular where exposed are much softened now by weathering. Fresh surfaces show to be of a gray color and rather fine-grained. The analysis of hydraulic limestone herewith given, being probably from this bed. Below this is eight feet or more of a much harder reddish, porous, magnesian limestone weathering to yellowish brown on the surface. A kiln was first built for burning the latter and later another for burning the softer gray limestone which is said to have produced the best cement. At first charcoal was used in the kiln but the last batches were made with coal slack.

A mill was erected for pulverizing the burnt limestone and this mill still stands with much of the machinery in a fair state of preservation. This consisted of the following: One Blake type crusher, one set of Cornish rolls (20 in. face 18 in. diameter), one 30 in. Buhr mill, (Bradford Mill Co., 8th and Evans St., Cincinnati); a bolting machine; an improved Eureka flour packer (Bernard & Leas, Moline, Ill.); a water tank, about a 35 h. p. engine, and a tubular boiler, 42 tubes 2½ in. x 16 ft. (Portsmouth Foundry & Machine Works).

The reason stated for discontinuance of the work was that the people of Vanceburg would not sell Mr. Love ground upon which to erect a warehouse for the storage of the cement.

The following are analyses of interest in connection with the possible use of the Silurian magnesian limestones of Lewis county for natural cements.

"No. 2482. (Vol. A. Pt. 2, Chemical Analyses, p. 289.) Limestone (hydraulic?) sent to Mr. Procter by W. J. Richason of Vanceburg. A dull gray, fine granular rock, with faint lines of stratification. Adheres slightly to the tongue."

"By calcining at high heat is a good hydraulic limestone, not tried with sand." This is below the average limestone used for such purposes in its clay and silica content.

"No. 1085. Yellow magnesian limestone. Probably belonging to the age of the Upper Silurian. Salt Lick creek, four miles above Clarksburg, Lewis county.

"A brownish-buff, porous limestone. Exterior surface so soft as to be scratched by the nail, and full of fossil casts of entrochites and bi-valve shells. Interior not adhering to the tongue and glimmering with numerous facets of yellow-brown calcareous spar. Powder of a gray-buff color. Dried at 212° F. it lost 0.40 per cent. of moisture. Valueless as a natural cement material. Composition air dried."

	No. 1085	No. 2482
Carbonate of lime	55.240	48.790
Carbonate of magnesia	27.820	37.482
Alumina and oxides of iron and manganese	12.280	2.490
Phosphoric acid .....	.207	.143
Sulphuric acid .....	.152	....
Potash .....	.167	.490
Soda .....	.126	.058
Silica and insoluble silicates	2.580	10.000
Water and loss	1.428	.547

Mississippian limestone sections.—The following section was obtained on the border between Lewis and Carter counties about 1 mile from Deep cut:

	Ft.	In.
Conglomerate sandstone.		
Mississippian limestone 30½ ft.:		
Semi-Lithographic limestone with some brown flint.		4
White finely crystalline limestone.	6	..
Brown compact limestone.		6
Five-grained oolite. 6 to	8	..
Red specked oolite, thin layers.	12	..
Fine oolites.	10	..
Reddish shale.		
Greenish to brownish shale.		
Reddish shale.		
	Probably	

The following is a detailed section of the limestone at Collier's Quarry, Berry Switch, near Tygert, Carter county. The rock is quarried by contractors at 25 cents per ton. Deep holes are drilled 15 feet back from the face which after springing with 7 to 8 lbs. of dynamite are broken with 75 to 250 lbs. of powder. Large lump rock sells at 40 cents per yard; small lump at 45 cents.

SECTION AT COLLIER'S QUARRY.	Feet	Inches
Sandstone above.		
Reddish, chocolate colored marl	4	..
Green and mixed colored marl	5	..
Light gray compact crystalline crinoidal limestone with some calcite facets with occasional small cavities, and greenish siliceous streaks; two layers	2	..
Lighter gray, less siliceous limestone, but otherwise as last	1	6
Fossiliferous shale; hard in upper part .....	..	8
Gray compact crystalline limestone	2	..
Light gray fine crystalline limestone, 5 layers	2	..
Cream white semi-oolitic crystallized limestone with much calcite, slightly siliceous (94 per cent pure)	2	..
Cream white oolitic crystallized limestone slightly siliceous (94 per cent. pure)	6	..
Reddish-gray compact crystalline magnesian limestone with calcite facets .....	..	10
Compact magnesian limestone	2	2
Rather compact gray, but brownish with iron stains where weathered, magnesian limestone	1	..
Somewhat compact, slightly siliceous, somewhat fossiliferous gray limestone	4	..
Dark gray with reddish crystalline limestone	4	..
Phosphatic marl, dark gray with red in center	1	6
Dark gray irregular semilithographic limestone .....	..	8
Semilithographic limestone, light gray (would weather brownish) with irregular veinlets and small crystals, one 4 and one 16-inch bed	1	8
Semilithographic stone, not differing much from last	1	..
Blue compact limestone with fine crystals and shale fragments through it, about	5	4
Light gray fine-granular limestone—a beautiful stone, 3 beds, 6, 8 and 24 inches	3	2
Gray compact limestone with small dark calcite crystals disseminated through it, splits into four strata, about	5	..
Gray, porous, siliceous oolite	7	..
Compact gray, somewhat argillaceous limestone, mottled with irregular horizontal calcite seams; some iron seams	6	..
Crystalline cemented breccia of compact buff gray limestone	4	..
Greenish-gray compact crystalline limestone with calcite facets .....	..	8
Grayish-white siliceous oolite at base of present quarry	4	..
Greenish-gray slightly siliceous compact limestone	4	..
Blue shale .....	..	4
Greenish-gray, siliceous semioolitic limestone	2	9
Green, siliceous matrix with brown calcite fossils, <i>phillipsia</i> , <i>spirifer</i> , etc., shelled into numerous layers	9	3
Total, 93½ ft.		
Greenish freestone at top of Waverly.		

The Lawton Sand and Supply Co., also have a limestone quarry in proximity to their sand plant at Tygert, Carter county.

The Limestone Mining Co., (R. A. Carpenter, Mgr.), have quarries at Limestone and at Berry. The section at Limestone is as follows:

	Feet.
Surface debris.....	6
Thin limestone "boulder rock".....	12
White oolite, two beds.....	8
Compact magnesian limestone, "kidney rock".....	12
Red and greenish marl (For analysis see under clay).....	3
Heavy limestone beds to base of quarry.....	24
Total.....	59

The limestone dips southeast. Culling out the marl the remainder is all sold for ballast at 55 cents a yard, (3 x 3 x 1 feet) except the screenings through $\frac{3}{8}$ inch screen which brings \$2.00 for use for walks, etc., around railroad stations. The rock from the Berry quarry is all sold as flux at 45 cents per yard.

The limestone is quarried by drilling nearly vertical holes 16, 21 and 24 feet, placed 8 feet from the face. With eight holes using 450 lbs. dynamite, 3,000 yards was broken. Judson F powder in stick form is commonly used to load holes after springing with dynamite, using from 150 to 300 lbs. of powder per hole. The cost of moving the overburden dirt is 20 cents per yard; quarrying stone 30 cents (formerly only 25 cents); and loading quarry cars (of which there are five) is 7 cents. Strippers are paid \$1.20 and drillers \$1.50 per 10 hours. At Berry the rock is quarried on contract at 25 cents per yard.

The plant is located at Limestone and has a capacity of 250 yards per day. The rock is dumped by quarry cars into a tip bin, whence it is raked with a long hook into a No. 5 Austin gyratory crusher. The latter takes rock 18 x 30 inches, larger sizes having to be sledged. The crushed rock is elevated by means of a 15-inch open-cup elevator which dumps into a small sheet iron hopper, the rock going thence into a long double trommel screen, which makes four sizes and oversize which goes back to be recrushed; outer screen has $\frac{3}{8}$ inch perforations, the inner screen $1\frac{3}{4}$, $1\frac{1}{2}$, and $2\frac{3}{4}$ inch perforations the last two being sold together. The sized product goes into a hopper with three partitions. The hopper has a capacity of 100 yards or about two cars. The screen house has a height of about 35 feet. Power is supplied by a 30 horsepower Iron-ton engine and a 45 horsepower Atlas boiler (which uses 50

bushels of coal per day). The cost of crushing which is contracted is 5 cents per yard. (At some of the quarries it is said to cost 7 to $7\frac{1}{2}$ cents.) From two to three men are required to run plant, one engineer and one or two at crusher. The cost of the plant was about \$6,000.

The cost per yard (3 x 3 x 1 feet) may be summed up as follows:

Quarrying.....	.30
Loading quarry cars.....	.07
Crushing.....	.05
Other costs about.....	.04
	.46

There is another quarry at Lawton operated by the Lawton Limestone Mining Co., Jesse Lane, Mgr.

Section near head of Dry creek and Wagner fork of Crany creek.

	Feet	Inches..
Lower coal measures and conglomerate.....	268	..
Mississippian limestone, about 42 ft.		
Covered interval.....	10	..
Gray crystalline limestone.....	8	..
Limestone with thin layers of green shale between and green spots in limestone.....	3	..
Covered interval.....	4	..
Cherty limestone.....	5	..
Compact limestone, some semi-lithographic fragments....	2	..
Fine grained brownish limestone, partly brecciated and cemented with white and black calcite.....	1	..
Compact fine grained limestone probably suitable for natural cement.....	3	6
Covered interval.....	1 to 2	..
Green calcareous crinoidal sandstone.....	1	6
Green plastic shale, perhaps more than.....	3	..
Waverly shelly sandstone.		

Lithographic stone and Brown marble.—In the southwest corner of Rowan county and two miles distant across the Licking river at Yale, two lithographic stone prospects were examined, and in the same sections brown marble occurs.

The lithographic stone occurs 40 feet above the base of the Mississippian limestone and is underlaid by granular

crystalline limestones. The best lithographic stone varies from 15 to 24 inches thick in layers of 2, 2½, 6, 7, and 8 inches each. It is light-drab in color and carries occasional iron oxide seams up to one-tenth of an inch wide and narrower calcite seams. Large slabs are easily quarried but only small blocks sufficiently free from these seams to be of value are obtainable. The fresh stone will probably prove blue-gray colored, and only 10 to 15 inches may prove workable. Above this bed layers of similar stone occur, 12 feet thick, which, however, contain irregular flat layers or rounded nodules of flint, both flint and stone being brecciated perhaps as a result of weathering, the stone containing also abundant small calcite crystals. Where fresh this bed might yield some workable lithographic stone.

Two beds of light-brown coarsely crystalline marble, aggregating 24 to 40 inches, where measured, but said to be thicker, occur 30 to 33 feet above the lithographic stone. This marble is suitable for interior decoration.

The following section of Mississippian Limestone, made on J. M. Cassidy Hill at Yale, Bath county, is typical of the region:

	Feet.	Inches.
Light-gray and semi-oolitic limestone.....	15	3
Covered interval.....	12	0
Gray granular-crystalline limestone.....	..	4
Brown granular-crystalline limestone.....	..	5
Brown marble.....	2	0
Covered interval.....	15	3
Flawed lithographic stone with more or less chert.....	12	5
Pearl-gray lithographic stone.....	1	3
Gray coarse, but chiefly granular-crystalline limestone.....	9	10
Brown crystalline limestone.....	2	6
Gray granular-crystalline limestone, 2 to 4 inch beds.....	21	6
Covered, but probably limestone.....	5	5
From depot at Yale to base of hill, including Waverly group and some Ohio shale.....	264	0

Oil and Gas.—While a large number of wildcat wells have been drilled in both counties, no intelligent prospecting has been done. Such wells as have shown oil and gas

have largely been on or near the axis of a monocline striking about N. 25° E. from Ragland and passing just west of Morehead and on through Lewis county two miles or so east of Vanceburg. It may be that if this axis were located accurately further prospecting for oil and gas in these counties might prove more encouraging. A topographic base and a careful stratigraphic and structural study together with two or three properly placed wells would be necessary to determine. Whether the more westerly monocline would offer anything in the Trenton rocks might be similarly investigated.

The great bulk of the wells bored have been dry—in fact the only productive wells of consequence are those in the southwestern corner of Rowan county, forming part of the Ragland oil field.

From the data at hand the probable location of the sands which show some flow of gas or oil is as follows:

Waverly	Cuyahoga?	Slight oil flow.	Cherry Camp of Straight fork.
	Bedford:	Gas constant flow wasting.	Triplett creek.
Devonian-Silurian	Corniferous-Ragland sand:		Regular flow pumped: Alfrey land.
	West Union A little gas on Laurel creek probably from this horizon.		
Silurian	Clinton?	Gas in well at Vanceburg.	

Cuyahoga? Sand.—One half mile up Cherry Camp and about six miles from the head of Straight fork, Lewis county, a well was drilled on the Eli Bryant land which yielded, at a depth of between 90 and 120 feet (according to Mr. Stern), one-half to one barrel of oil per day. Judging from the depth and the fact that the surface here must be in Cuyahoga, think it likely that the flow was probably from a bed in I that formation. This well was drilled 600 feet at which depth salt water was had. The wells at the head of Straight fork near Awe were dry. These were on the Gus Propes, Knight (now Stein), and Wm. Halbert (now Wm. Stone) lands. The deepest was 1100 feet.

Two dry wells were bored 1000 feet at Martin, in Lewis county, while two miles west another was put down which cut the Lexington limestone but was dry except for a little gas.

Bedford sand.—Since our sections show Berea thinning rapidly southward, the flow of gas (which has been burning most of the time in a flame about 18 inches in diameter and of like height) on the Nelson Egan (formerly Sam. Reyburn) land, must come, judging from the record, from a bed of the Bedford member of the Waverly. The section as reported by Hoeing (Bull. 1, Norwood series, Ky. Geol. Surv., p. 62) is as follows (the geological designations are my own):

	Feet.
Soil.....	5
Cuyahoga..... Blue shale.....	62
Sunbury..... Black slate.....	10
Bedford-Berea..... Blue and green shales, gas at base.....	94
Ohio..... Mixed shales.....	29
Ohio..... Red rock.....	6
Ohio..... Black shale.....	329
Corniferous..... Soft lime (oil and salt water).....	7
Total depth.....	542

Other wells in this vicinity were drilled on the Tom Adams land, one of which was 565 feet deep. The gas was not strong here, but it yielded five barrels of oil per day until plugged. These wells were drilled by Hon. R. S. Triplett, of Owensboro, in 1901 and are four miles northwest of Triplett P. O., and 12 miles northeast of Morehead, in Rowan county. It is fully 150 feet higher to the base of the Mississippian limestone and 230 feet to the top of the ridges.

Just northeast of Ragland, across the Licking river in Rowan county, is the Alfrey land which forms a continuation of the Ragland oil field. The Ragland sand is a part of the Corniferous-West Union limestone and lies shortly beneath the Ohio shale. The following are average sections from the numerous wells of this field:

Ragland Wells, (after Hoeing) Bath County.			Alfrey Wells. Scotts Creek Wells. Rowan County. Rowan County.			
Feet.			Feet		Feet.	
Waverly	{	Gravel.....	20	Earth and gravel...	50	6 to 11
		Blue shale.....	167	Soft sandstone....	12	7
				Black shale.....	30	40
				Fireclay.....	8	8
Ohio Shale..	{	Black shale.....	205	Soapstone.....	12	12
		White "fireclay"...	8	Black shale.....	200	200
		Brown shale.....	12			
Coniferous		Oil sand.....	14	Oil sand.....	20	35
426			342		313	

The average depth of the Alfrey wells is about 330 feet. A comparison of these records shows that the Bath county wells are started on higher land and hence a greater thickness of Waverly to go through. The Ohio shale is about the same thickness on both sides of the Licking river. It looks as though the fireclay and brown shale have changed positions on the east side of the Licking so as to be above instead of below the Ohio shale. It may be that the records as given me were incorrect or it may be that the "fire-clay" and "soapstone" in the Rowan county sections are the equivalent of the ten feet of white and gray shale reported by Hoeing in an outcrop section from eight miles northwest of the Ragland field.

Some 37 wells were drilled on the Alfrey land by the Morehead Oil and Gas Co., (Hiram Bradley, President, Morehead, Ky.,) of which one was lost; one has tools in it and 35 are pumping black oil. The last are the only producing wells in Rowan county. This company also drilled a dry well one quarter mile east of Cogswell on the H. N. Alfrey land. The oil was obtained from three to four feet below the top of the Ragland sand in the producing Alfrey wells. The oil sand dips southeast. The fall is about 25 feet in going $2\frac{1}{2}$ miles southeast of Cogswell.

The plant, for pumping the oil and separating the water and gas from the petroleum on the Alfrey land, consists of an Acme power machine (Toledo) to which the

pumping rods for the 35 wells are connected and which operates their pumping jacks. The maximum length of rods is 900 yards. There are two 35 horsepower boilers which supply steam for the 15 horsepower Parkersburg engine and for the separating tanks. They have a 20 horsepower Bessemer gas engine but not sufficient gas is separated to run it. Steam coils are utilized for heating the separating tanks. On passing from the gas separator to the water separator it is heated to 95° F., at which point the water is separated. The oil goes into the pipe line at a like temperature. There are ten storage tanks of 250 gallons each. They pump only half the time as the demand is slack, the average being about 1200 bbls., per month. The plant is cared for by two pumpers and a boss, the wages being \$45 per month for the former and \$50 for the latter.

Some idea of the requirements and costs of drilling may be gained from the following: The cost of drilling on contract is \$1 per foot. If a company owns and operates its own drill, the cost is 75 cents per foot. The casing costs about 50 cents per foot (the Alfrey wells required 130 feet each). The casing is of 6¼-inch pipe. The 2-inch pipe used costs 4 cents per foot. Pumping jack rods, 2 inch pipe, etc., costs about \$40 per rig. A tripod is necessary for cleaning out wells, a block and tackle being used in connection to hoist the rods, etc. The cost of pumping is 20 cents per barrel.

A considerable number of wells were put down on Scott's creek south of Cogswell. The Kentucky Ragland Oil Co., (of Frankfort), put down 16 wells on the Andy Thomas land, and 18 wells on the Widow Jones land near the Licking river. The Bradley, Riley Co., (of Morehead) put down two wells on the John Reed land, two on the Louis Ratliff and others one mile and one mile and a half up Scotts creek, all of which were dry. They also bored a well on the Bradley land, one mile and three-fourths north of Cogswell, which showed some good oil, while another deep well put down by them on the Adrian Coldiron place, two miles east of Freestone, on Triplett creek, was dry. The Mutual Oil Co., (Davidson) put down

four wells on Judge Cogswell's farm, one mile west of Cogswell, from which some oil was pumped by the Kentucky Ragland Co. Some wells were drilled on Works run but proved dry.

West of Morehead, there were a number of dry wells put down partly by Davidson, Bradley and Nichols. Two wells, salt water in Ragland at 400 and 500 feet depth, and one well (by Standard Oil Co.) 1,700 feet, one mile west; one well on Coldiron land, two miles west; wells on Al. Gayhart, two and three miles west, reached Ragland sand (according to Dave H. Evans, driller), at 340 feet, and were 1,100 feet deep with limestone in the bottom.

Four miles south of Morehead, the dry Ragland sand was passed through at a depth of 502 feet on the Morgan land, and one mile further south, on the West Liberty road, a dry well on Boone Payton's place was put down 300 feet and has brown shale in the bottom. On Tom Dillon's (McDaniels?) land on Crany creek is a 900-foot well and according to Cave H. Evans, the driller, they drilled ten or twelve feet into the second sand; the Ragland sand is in the bottom, above which is 24 feet of black slate, and then 24 feet of "fireclay".

On Christy creek five to six miles southeast of Morehead, the Standard Oil Co., are said to have put down two 1800-foot wells (Judge Nichols, informant). The Butts farm well, 1560 feet deep, the record of which is here given and which Hoeing reported (Bull. 1, p. 62) is probably one of these wells:

	Thickness.
	Brown quicksand..... 25
	Hard, white lime..... 50
	Open, white lime..... 75
Waverly, 425 ft.	White shale..... 80
	White lime..... 110
	White shale..... 110
	Brown shale..... 40
Devonian, 245 feet..	White sand..... 10
	Brown shale..... 190
	White fire-clay..... 5
Coniferous and Niagara, 205 feet.	Ragland sand (salt water)..... 100
	Red rock..... 50
	White shale..... 55
Clinton and Cin- natian 660 ft.	Lime shells..... 200
	Hard lime..... 460
	Well is about down to top of Lexington limestone.

Two miles east of Morehead, (according to Judge Nichols), a well was put down 500 feet, there being 18 to 20 feet of the Ragland sand in the bottom with salt water. A well on the Bivans land near Martin, Lewis county, yielded some gas, but its depth is not known.

Oil shale.—When the present reserves of petroleum become greatly reduced in this country, the Ohio shale may yield oil upon proper retorting, with sulphate of ammonia and coke as by-products. The shale carries about 11 to 12 per cent. volatile matter. Oil is distilled from shales in Scotland and France at the present time, over 2,000,000 tons of shale being retorted a year in the former and about 200,000 in the latter country. Both of these countries have no other oil resources. The Scotland shale averages 23 gallons oil per ton, the lowest shale worked yielding 16 gallons. The Devonian shale would be unlikely to yield over eight or ten gallons oil per ton. The cost per ton of royalty, mining and retorting and refining in Scotland averages about \$1.89 according to D. R. Stewart.* Fair dividends have been paid by the operating companies for several years past. In this country, the cost of quarrying would be 50 cents, if done by improved methods with steam shovel and on a large scale as against \$1.14 average cost in Scotland. The difference in cost is due to the fact that in Scotland thin seams are worked similar to coal beds, where as here the thickness is great on the outcrop and large tonnages can be removed by stripping. The retorting and refining costs per gallon, however, would be considerably greater because of the considerably less yield per ton handled. It would be impractical to attempt the distillation of these shales in competition with petroleum at the present time. An attempt was made on a small scale to distill these shales at Vanceburg a number of years ago, but was unsuccessful.†

Sand and Gravel. Molding sand is found on the lands of Robt. Collins, Jas. Long, George Davis, and Rache Burris, three and one-half miles northeast of Vanceburg. The bed

*The Shale Oil Industry of Scotland, Economic Geology, Vol. III, No. 7, 1908, pp. 573 to 598.

†A more probable utilization of these shales seems to be for the production of gas.—C. J. N.

is at least 12 feet thick and many be seen for nearly one-fourth mile on the southwest side of Sand branch.

The hills in the vicinity of Morehead are capped with as much as 65 feet of sandstone Conglomerate formation suitable for making bottles, common flint, and window glass.

Near the Carter line, on the Trace-Eby road in eastern Lewis county, the following section of sandstone caps the Mississippian limestone:

Reddish sandstone.	Feet
White sandstone.	8 to 10
Reddish sandstone.	4

The white sand could be used for glass as it is and the red sand no doubt improved by washing for similar use.

Notes are added concerning a Carter county plant, which may be helpful and suggestive of what may be done with the sandstones of the Conglomerate formation of the eastern parts of Lewis and Rowan counties.

The Lawton Sand and Supply Co., of which Mr. Charles Norton of Louisville is President, have a sandstone quarry and crushing plant at Tygert, Carter county.

The sand quarry shows the following section:

	Feet	Inches
Surface debris, 1 ft. 3 in. to	1	6
Glass sand, white massive, with a few black grains, but laminated with brown bands near top, medium sized grains, two beds 20 to	18	..
Hard quartzose but porous sandstone, gray somewhat brown striped "ganister"	2	..
Discolored sandstone to base of quarry	14	..

The glass sand ledges are shot separately from the others at the quarry. The drilling is done by hand. The quarry foreman states that the holes are sprung with nine sticks of dynamite, after which they are shot with 30 lbs. of Judson 4F powder. The boulders are broken with 16 and 18 lb. sledges at the quarry to a size suitable for the crusher. Eight to nine men are employed in the quarry,

the wages paid being \$1.15 to \$1.25 per day. The sandstone is said to cost 20 cents per yard loaded on the small tram cars, which are mule drawn and deliver the rock to the plant about 100 yards distant.

The plant consists of a No. 3 Austin gyratory crusher, two sets of 18 x 24 inch rolls, one 12-foot and three 10-foot log washers and a 12-mesh screen, 4 x 5 feet. The washers are 15 inches in diameter, spiral with an occasional split, and are set at a pitch of two feet. The pebble oversize from the screen, I was told, is sold for concrete and brings 40 cents per yard, f. o. b. cars; the undersize or sand, is sold for glass and brings a better price, how much was not learned. The power is supplied by what the engineer claimed to be a 175 horsepower engine and a 100 horsepower boiler. The cost of crushing and washing according to the same authority is about 12.5 cents and of loading on the freight cars 9 cents.

Sandstone gravels are abundant in many of the creek beds, erosion gravels of Waverly sandstone for the most part. These are suitable for road building.

Roads and Road Materials.—The roads with few exceptions are as poor as any in Kentucky, and yet nowhere is there a better supply of good road materials. The majority of the roads follow stream beds and are almost impassible in the wet season. The Richmond-Maysville limestones, in western and northern Lewis, the Mississippian limestones in eastern Lewis and Rowan, the hard iron-seamed sandstones of the Waverly, and the gravels of the stream beds are all excellent road materials, and in addition there are the Clinton and West Union limestones and the Ohio and Sunbury black slates which, while inferior to the others, can be used where necessary. Thus every part of these counties is supplied with suitable road materials, and nothing would so add to the advancement of these counties as the use of these materials in the making of good roads. The recent installation of a 250-ton crusher plant by the Kentucky Bluestone Company will afford crushed rock in western Rowan.

Water Supply: Mineral Springs.—Lewis county is especially well supplied with spring waters, and Rowan to a less extent; and in addition, an abundant surface water supply in the rivers which adjoin and the many creeks which drain the counties.

There are both fresh and mineral springs. The horizons at which springs have been noted are as follows:

Lower Coal Measures.—Just beneath coal 70 feet above base.

Conglomerate sandstone.—Not far from top—fresh water.

Mississippian limestone.—Not far above base; excellent flow of hard water noted near head of Wagner fork of Crany.

Waverly Group.—Springs issue from between freestone ledges of the lower Cuyahoga; fresh water, especially noted in Lewis county. Others were noted at about 100 feet and 230 feet above the base. In Rowan county, at the quarry at Van Antwerp, just above the Buena Vista member of the Cuyahoga is excellent fresh water.

Ohio Black Shale.—From eight to twenty-two feet above the base is a notable sulphur water horizon from which issue many springs, the best known in Lewis county being the Esculapia and Glenn springs. Chalybeate waters also issue from this horizon.

West Union Limestone.—Near the base of this limestone is the great magnesian spring horizon of Lewis county. The springs are numerous and many of them quite large. On one farm of 465 acres as many as fourteen springs issue from this rock, the largest having a four-inch flow.

Clinton Limestone.—This also supplies a mild magnesian saline water. Springs are not abundant because of lack of outcrops, but the towns of Burtonville, Epworth and Tolesboro draw their water supply from this rock.

The following analyses show the character of the mineral springs of the Ohio black shale and West Union limestone:

CONSTITUENTS OF MINERAL SPRING WATERS, GRAINS PER GALLON.

Constituents	Esculapia White Sul- phur	Esculapia Chalybeate	Glenn Chalybeate	Glenn Magnesia	Esculapia Magnesia	Glenn Alkaline
Analyst. . . .	R. Peter ¹	R. Peter ¹	W. Dick- ore ²	Dickore ² and Morgan	McHargue ¹	Dickore ²
Alkaline car- bonates	3.268	11.948	6.760	20.409	13.77	27.745
Sulphates. . .	63.592	27.632	8.030	8.100	14.81	4.362
Iron salts. . .	0.368	2.364	12.550	0.856	0.21	0.360
Chlorides. . .	109.312	.520	0.870	1.359	0.67	3.420
Total solids.	196.480	51.490	29.500	32.044	32.32	38.131
Sulphuretted hydrogen gas, inches. .	5.464	.....	.....	.....	.....	..
Carbonic acid gas in inches. . . .	...	4.150	....	....	....	....

1. Analyses made in the laboratory of the Kentucky Geological Survey. The flow of the Esculapia magnesia spring is about 17 gallons per hour.

2. Taken from book issued by the Mr. Walker, present owner of Glenn Springs.

The Esculapia white sulphur springs, which issue from the Ohio shale 15 to 22 feet above the top of the West Union limestone several hundred yards south of the Esculapia Hotel (Dr. C. M. Beach, proprietor), would be classed according to Peale's classification as a sulphuretted calcic sodic muriated alkaline-saline water.

The Esculapia chalybeate water issues from the Ohio shale a few hundred yards west of the Esculapia Hotel and is a mild carbonated chalybeated sulphated alkaline-saline water.

The Glenn chalybeate water differs from the above in a greater amount of iron oxide, and lack of carbonation. It issues from the gray shale immediately below the West Union limestone. It was stagnant at the time of my visit.

The Glenn magnesia spring is also in the shale at the base of the West Union limestone. It is a half-inch stream of clear tasteless water. The Esculapia magnesia spring comes from the base of the same limestone, a few hundred yards farther around the hill to the south than the Escula-

pia sulphur spring. These magnesian springs are a mixed type lying between the weak alkaline calcic-magnesian and weak alkaline-saline, sodic-magnesian sulphated water.

Salt.—Regarding the occurrence of salt brines near Vanceburg, Dr. Owen (Ky. Geol. Survey reports, Owen series, Vol. 3.) says:

“Borings have been made for salt in the vicinity of Vanceburg (on Salt lick on the Pollitt and other farms) but with what success I am not informed. But since these borings were commenced near the base of the junction of the magnesian-limestones of Upper Silurian date, they must have passed through the encrinital beds belonging to the Clinton group, the twenty to twenty-five feet of marl underlying it, and then into the blue limestone formation; the character of the rock they penetrated was not favorable for obtaining strong brines. The flinty magnesian limestone, near low water of the Ohio river, at Vanceburg, often affords efflorescences of sulphate of magnesia, and sometimes weak brines, but as this rock is only, at most, forty to fifty feet thick, it is not likely to afford any considerable store of salt.”

Mr. Stein tells me that salt water was obtained at 100 feet at Light plant, and at the Fair ground at a depth of 110 feet; also at the mill at Vanceburg.

Springs and Water Supply.—The following sundry notes on springs and water supply were collected:

A number of fine springs issue from the Lower Waverly four-fifths of a mile southwest of Garrison.

Good freestone springs were noted on the Tony Hays and Dyer Bros. lands on the Garrison road four and three-fourths, and five miles, respectively, northeast of Vanceburg.

Three-fourths of a mile south of Vanceburg is a chalybeate spring, while a quarter mile further south, on the Kinniconick road, a spring issues above a red and gray mottled clay.

One and a half miles from Vanceburg, on the Mrs. Kate Pollitt land, there is a sulphur spring; while the same distance out the Quicks Run road there is a chalybeate spring on the Widow Gouldenburg land. Not far from

Black Jack school house on the Pleasant Hill road is a half-inch chalybeate spring on the George Puark place.

A freestone spring of about one-inch stream issues on the Lige Graham land two-fifths of a mile south of Martin.

A half-mile east of Martin on the Stewart Campbell land a number of springs issue from the base of the West Union limestone. A spring issues from the same rock one and a half miles south of Carrs on the Martin road. South of Pence station on the Verner Dryden place are fourteen springs at the same horizon, the largest of which measures four inches, while a half-mile to the south of these is the Meyer spring.

Four-fifths of a mile east of Poplar flat, also at the base of the West Union limestone is a good spring in Cold Spring hollow.

The Kirk springs near Burtonville are on the William Cropper land.

The water supply of Tolesboro is obtained fifteen to twenty-five feet below the top of the Clinton formation.

On the Esculapia-Burtonville road on the west of the Esculapia hill a spring issues twenty-five feet above the first Cuyahoga freestone ledges.

Seven small streams of chalybeate water issue from the Ohio shale on the Omar Fuller and Grant Hall lands, and another 200 yards back on the Insko place, on the left of the road leading to Meyers store, one and a half miles from Glenn post-office. Three-fourths from the latter place is a white sulphur spring.

At Morehead the water supply is obtained from shallow wells, 15 to 25 feet deep, (surface drainage); drilled wells yield soft water from the base of the Waverly at depths of 40 to 80 feet; and in one case sulphur water at 80 feet, probably from the top of the Ohio shale.

The wells at Farmer are chiefly at depths of 15 to 30 feet in the Ohio black shale. A good spring occurs a short distance above the Buena Vista beds at the quarry of the Rowan County Freestone Company.

Zinc Ore.*—The zinc prospects are confined to a narrow vertical range of strata, the upper part of the West Union limestone, and to Lewis county. (Aside from this, occasional bits of zinc blends may be expected in the carbonate iron ores of the Waverly and Mississippian horizons, but are of no importance.)

In the West Union limestone, the zinc occurs as the mineral zinc blende, zinc sulphide, and is of good quality but contains some iron. It occurs either in the form of nodules in the limestone or cementing thin seams or angular fragments (breccia). Nodules of solid zinc blende weighing as high as six pounds each occur, but the nodules are for the most part sparsely distributed through the rock. The zinc blende is sometimes partly altered to zinc carbonate and often has a coating of this mineral and sometimes, in addition, of iron oxide. The rock in which it occurs is a red, yellow, or blue magnesian limestone containing more or less sand. The fresher layers are blue in color. The more calcareous layers which carry the zinc ore sometimes contain fossil crinoid beds abundantly and alternate with more sandy layers which carry little or no zinc.

Reference should be made to the chapter on Stratigraphy for a general section of the West Union limestone.

Among other distinguishing features of the zinc-bearing beds are their more often reddish color and pitting, with cavities 1 to 4 inches across. Originally such cavities were filled with the fossil shells, *Whitfieldella*, or perhaps some of them by the coral, *Cyathophyllum*. Upon the leaching or rotting of such fossils, the weight of the superincumbent beds caused such beds to collapse to some extent, which explains their partially brecciated condition, while beds above or below show no fracturing worthy of note.

Such cavities were afterwards filled with zinc blende by water solutions circulating through these beds which collected the zinc originally distributed in small amounts throughout the same beds. The zinc originally had been

*The most of the zinc prospects were examined in July, 1908, Mr. T. C. Carroll assisting me at that time, to whom thanks are due, as well as to Mr. Rudd T. Neel of Huntington, W. Va. and Mr. Regenstein of Covedale, Ky. for aid in facilitating the investigations.

precipitated together with the iron by means of the organic matter plentiful in the sea at the time the beds were laid down. Much bituminous matter is still preserved in these beds. Since the beds above and below remain unfractured there could have been no trunk channels which could have supplied solutions to these beds, and it is evident that the amount of zinc which the beds themselves could supply must be necessarily small, so that only in rare instances locally would the beds be likely to carry a sufficient percentage to result in a profitable zinc content. It is unlikely that any of the layers except those actually showing some zinc in the form of zinc blende are worthy of further investigation.

The pittings are not all due in the calcareous layers to the leaching out of zinc blende though many have such an origin; some of them are the result of leaching to calcite nodules or of fossils. Some of the reddish sandy layers or beds that intervene between the more calcareous beds are also pitted on the outcrop from the washing out of softer sand so that care must be taken not to confound such with the zinc pittings.

The fresh unweathered limestone will not show any pittings but will carry unaltered zinc nodules and seamings and since none is leached out it should occur in such rock in greater abundance. Should any prospecting be done in the more favorable sections, such as in the Salt Lick valley about four miles to the south of Vanceburg, the object will be to test the percentage carried by the unweathered portions of the layers. This can best be accomplished by running entries or drifts, not exceeding four feet in width or five or six feet in height on the more favorable levels. Should it be desirable to prove a level above or below it will be best to start it some distance from the first so that they will not interfere with one another and be safer. It will be necessary that such drifts be run from fifty to one hundred feet into the hill, and that they be started under as much cover as possible to begin with, so that the unweathered rock may be reached quickest. At least two or more drifts on any level and at least 1,000 feet apart will be necessary to prove the bed. The cost of

driving will be \$4 to \$6 per foot. Or, instead of this, a number of drill holes might be put down to intersect the zinc-bearing beds. This on the whole might not prove as satisfactory as the first method owing to the sparsely distributed condition of the nodules. Any bed to be workable must be not less than three or four feet thick and must carry at least 10 per cent. of ore. Such ore when concentrated by a mill especially designed for the purpose would bring about \$30 to \$45 per ton, according to the percentage of zinc the concentrate runs.

The following notes were collected on the several prospects:

J. N. Hughes prospects.—Prospects were opened at two points on the Hughes land, which is three miles south of Concord. Zinc blende occurs in nodules with coatings of zinc carbonate and iron oxide, scattered through yellow magnesian limestone. It also cements breccia and horizontal and vertical seams. In this vicinity the total vertical range so far as known is 16 feet 3 inches. At 3 feet 7 inches above the lowest layer and at the highest layer are the levels upon which these prospects are opened. The top-most layer is separated by a thin white to black kaolinic clay and limestone, 11 feet 6 inches thick from the Ohio black shale above.

Regenstein prospects.—These adjoin the Hughes. The occurrence is similar only it is opened at the lowest zinc bearing layer and at one 12 feet 9 inches above it. Fetter's land, to the south, shows a full section of the West Union limestone in outcrop, but no zinc was seen.

Richard Kennedy prospect.—This prospect is three-quarters of a mile southeast of the Regenstein. Here zinc occurs in similar manner but is only separated by about 6 feet of limestone from the Ohio shale. Only one layer has been found three to four feet thick. The limestone is unweathered, granular and of a bluish-gray color. The shale rests unconformably here upon the West Union limestone.

Lee Polly prospect.—This is something more than a mile east of the Regenstein. Here zinc occurs in similar manner and of like horizon; except that the limestone is granular, contains crinoid beads and is red in color.

It weathers to a soft reddish sandstone. The zinc blende is more abundant here than at any of the zinc prospects except the Kinney described below. It was not possible to determine the thickness of the valuable layers but the prospecting was not deeper than 5 or 6 feet.

Ham Moore prospects.—These are about one and three-quarter miles southwest of Carrs Station, about one mile from the river and about one and a half miles northeast of the Polly prospect. Open cuts show red limestone similar to that at Polly's at the top of the West Union limestone, and immediately below the Ohio shale, carrying zinc blende in seams and nodules, but not sufficient to pay. Here three feet of sandstone shale occurs at the top, the red limestone with crinoid beads is 9 feet 6 inches thick and the calcareous sandstone is exposed 4 feet 6 inches thick below this. The zinc occurs chiefly in the topmost layer of the limestone.

W. G. Stricklett Tunnel prospect.—The reddish limestone beneath the shale has been tunneled back about 50 feet. The upper 8 feet 6 inches carries some zinc blende and calcite nodules. One foot below this is a bluish sandstone, perhaps for 15 inches, which is barren. Below the sandstone and at 23 feet 6 inches below the Ohio shale a layer of limestone occurs carrying a small seam of zinc blende, it is said.

Capt. Thomas Kinney prospect.—This is in the Salt Lick valley, 4 miles south of Vanceburg just off the road to Glenn's Springs. It appears that the West Union limestone is here about 200 feet or more lower than the prospects south of Concord. This difference is explained by a thickening of the Ohio shale as well as dip coming east.

The zinc occurs through three consecutive beds, 6 feet thick in all, much pitted on the outcrop, and consisting of reddish and yellowish magnesian limestone. Below this

is two feet of calcareous sandstone, and still below is a bed containing an undetermined concave-shaped fossil; this bed is slightly phosphatic as well as bituminous. It may contain some zinc carbonate but this is doubtful. This is the only one of the prospects examined worthy of further investigation; others in the same vicinity may prove equally good, but it is best that one property be developed before others are tried.

Simon Lawhun prospect.—This adjoins and shows the same ledges as the Kinney, and some sample shipments are said to have been made.

Stewart B. Campbell prospect.—This is on Quicks run, seven miles from Vanceburg, near Martin postoffice. The prospect is near a spring. Zinc blende occurs in cavities in the limestone, with occasionally a bit of calcite also associated. The rock is of the same character as on the Stricklett and Moore lands. It was prospected to a small extent 45 years ago. Some of the upper rock shows a fair dissemination of zinc blende but not sufficient to repay working.

Morgan Cadwaller prospect.—About 30 years ago, on the Morgan Cadwaller place, prospecting was done, showing a prospect similar to the Kinney. A smelter was erected on the Fred Carr land, near Carrs, and some zinc white was produced, but not in quantity.

Other zinc prospects are on the Ayles, and Davis (now A. J. Stein) lands.

Conclusions.—The zinc ore of Lewis county is confined to the more calcareous beds of the upper 10 to 24 feet of the West Union limestone. It occurs in nodules and cementing breccia and seams. While of good quality, it is not likely to prove in quantity except locally. The region south of Concord is not worthy of further prospecting, but at Martin and in the Salt Lick valley region (four miles south of Vanceburg) further prospecting will be necessary to prove whether or not the deposits are of value; this prospecting must be done in the more promising unweathered beds.

Miscellaneous.

Coal.—These counties have no coal of value, except it be the lower Conglomerate coal which is from 12 to 36 inches thick locally in Rowan and may there be of local use. In Lewis no coal was seen. It was thickest, where it was prospected in Rowan county, near the head of Wagner and Dry creeks (see section under Stratigraphy—the Conglomerate and Coal Measures). About 70 feet above the Conglomerate is a coal 10 to 12 inches thick in southeastern Rowan. Sometimes one or both of these seams are entirely wanting. Leslie (Vol. 4, Owen, p. 462) states that on Day's branch of Miners fork the lower Conglomerate coal is wanting, 148 feet of massive sandrock resting directly on the limestone; but further north on Miners fork a 12-inch bed was once worked. The lower Conglomerate coal is marked by a streak of fireclay or by springs 8 to 18 feet above the Mississippian limestone. According to Owen, the lower Conglomerate coal is 18 inches thick at the head of Tygert creek. In the hills of eastern Lewis county no coal occurs between the fireclay and sandstone.

Iron ores.—Lewis and Rowan counties have no valuable iron ore deposits, despite the fact that the Clinton iron ore is had just over the border to the southwest of Rowan in Bath county; the Mississippian limestone ores of the Red River region occur just south of Rowan in Menefee, and the Mississippian and Coal Measure ores of the Hanging Rock region occur just east of Lewis and Rowan, in Greenup, Carter and Boyd counties.

The Clinton ore is under cover in Lewis and Rowan and in all probability has thinned too much to work anyhow. This ore is usually a red hematite.

The Waverly rocks contain near the base usually embedded with shale or in beds alternating with the sandstone and shales some hard blue carbonate ores, but in no case are these of sufficient extent to warrant development. Iron carbonate concretions were noted in the shales of Big Hill on the line between Lewis and Rowan counties.

Resting on the Mississippian limestone is a bed of

carbonate and hydrated oxide iron ores; the present writer did not see this ore at any of the exposures examined though it may have been present under cover. Owen (Vol. 1, p. 200) states that in Carter near the confines of Lewis he found this ore up to 4 feet thick, average about 1 foot, on the ridge which constitutes the divide between Kinniconick and Tygert creeks and that this ore carried about 50 per cent. iron oxide. In Rowan this ore would underlie a wider area in the southeastern part of the county, but for the most part would have considerable cover, too much to permit it to be worked at present even if thick and good enough. The following analysis is probably from such ore:

"No. 3246.*—Iron Ore, bed 4 feet thick (60 feet wide exposed) on the branch of Crany creek about 4 miles from its mouth in the southeastern part of Rowan county. Sample sent by A. J. Thurber, Sept. 1891.

"A tough, compact, dark gray carbonate of iron.

COMPOSITION, AIR-DRIED.

	Feet
Carbonate of iron.....	64.48
Carbonate of lime.....	4.00
Carbonate of magnesia.....	1.50
Alumina.....	5.63
Silica.....	19.00
Phosphoric acid.....	Trace
Moisture and loss.....	5.39
Total.....	100.00
Percentage of iron.....	31.13

"With this sample Mr. Thurber sent a piece from the bottom of the same bed. This proved to be the same ore, but somewhat oxidized and containing bright crystals of zinc sulphide."

The slates of the Coal Measures also show some carbonate and oxide ores but not in appreciable quantity in these counties.

No. 1083.—Saline efflorescence. Labeled "Copperas, from Devonain Black slate, near David Mifford, 8 miles from Clarksburg, Lewis county."

Yellowish-white porous, light lumps of saline efflorescence mixed with small fragments of slate.

*R. M. Peter, Bull. 3, Chemical Report, Kentucky Geological Survey, 1905, p. 69.

Composition, dried at 212°F.

Sulphate of alumina.....	25.585
Sulphate of iron.....	15.653
Sulphate of magnesia.....	1.000
Sulphate of alkalies.....	8.000
Slate and insoluble portion.....	1.000
Water and loss.....	48.762
	<hr/>
	100.000

Efflorescent crusts of epsom salt occur on the West Union limestone at Poplar Flat and at low water on Clinton limestone at Vanceburg.

Pyrite or fools gold, a brassy yellow metallic mineral (iron disulphide), occurs in specks, plates, and, in one case, in a vein in the Ohio shale.

A red ochre occurs in the Conglomerate formation in northeastern Lewis county which was once quarried for use in paints.